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Kansas City Area Project
Technical Report

Mid-America Regional Council, Kansas City, MO

Prepared for

Environmental Protection Agency, Washington, DC

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The nature of the urban runoff problems in the study area,

The severity of these problems,

The causes of these problems, and

The opportunities for controlling urban runoff problems.

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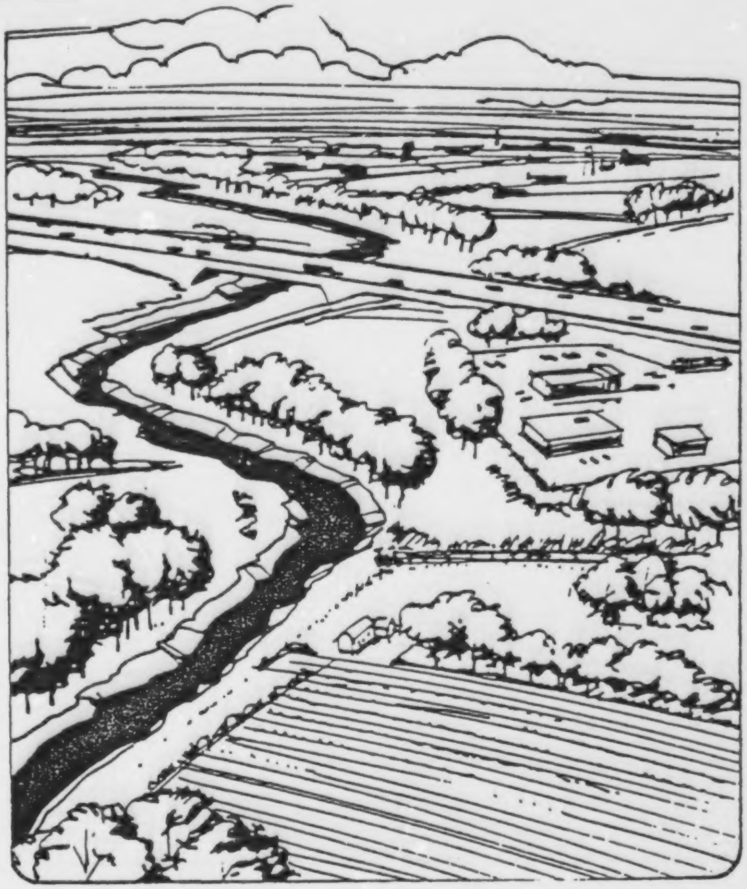
NATIONWIDE URBAN RUNOFF PROGRAM



Kansas City Area Project

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Submitted by
Mid-America Regional Council and F.X. Browne Associates, Inc.

TECHNICAL REPORT

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Submitted to:

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Johnson County Unified Wastewater Districts
U.S. Environmental Protection Agency

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Glossary

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1.0 OVERVIEW AND METHODS

1.1 INTRODUCTION

It is only recently that urban runoff has been considered a contributing factor to water quality problems. The Federal Water Pollution Control Act Amendments of 1972 signaled a heightened national awareness of the degraded state of the nation's surface waters. Congress responded to the new national awareness by mandating a national water quality goal of fishable and swimmable waters by 1983.

Section 208 of this act resulted in the designation of state and local water quality management agencies to integrate water quality activities. As point source discharges were increasingly brought under control and funds for the construction and upgrading of municipal sewage treatment plants were granted, the awareness of nonpoint sources as potential contributors to water quality degradation was heightened. Uncertainties associated with the local nature and extent of urban runoff water quality problems, the effectiveness of possible management and control measures, and the affordability of these measures in relation of their benefits increased as water quality management plans were developed. The unknowns were so great and control cost estimates so high that Congress deleted funding for the treatment of separate stormwater discharges with the Clean Water Act of 1977. Mid America Regional Council (MARC) 208 Water Quality Management Plan findings for the Kansas City metropolitan region regarding stormwater runoff were consistent with the uncertainties expressed nationally.

In 1978, after reviewing the past work on urban runoff by the 208 designated agencies such as MARC, the Environmental Protection Agency (EPA) determined that additional, consistent data were needed. To collect these data, EPA initiated the Nationwide Urban Runoff Program (NURP). This program was designed to build upon pertinent prior work and to provide additional practical information and insights to guide future policy, program development and implementation.

The local Kansas City Area NURP program was one of 26 model studies conducted throughout the country. The basic objective of the nationwide NURP program was to provide information to make the best possible policy decisions for federal, state and local involvement in urban stormwater runoff control.

The Kansas City Area NURP project was administered by MARC in cooperation with the City of Independence, Mo., and the Johnson County Unified Wastewater Districts.

1.1.1 PROJECT OBJECTIVES

The Kansas City Area NURP program was designed to meet national, regional, and local objectives. The objectives of each participant follow.

EPA NURP Objectives

The Kansas City Area NURP was one of 26 NURP studies selected by EPA for intensive data gathering and study in order to: (1) meet EPA program objectives; (2) develop implementation plans for the area; and (3) demonstrate the transferability of knowledge and solutions to other areas without the need for intensive data gathering efforts.

The overall objectives of the program were to· (1) determine the extent to which designated beneficial water uses are being impaired by urban stormwater pollution; (2) develop water quality criteria appropriate for the protection of water uses from the transient and persistent effects of stormwater; (3) quantitatively determine the sources of urban stormwater pollutants; (4) evaluate the effectiveness of abatement and control techniques (Best Management Practices - BMP's); and (5) develop strategies for the optimum wide scale deployment of BMP's.

Relative to the Kansas City Area NURP, these general program objectives can be translated into specific EPA objectives, which were:

1. To characterize urban runoff loadings by land use type,
2. To define the specific sources of urban pollutants,
3. To determine the short and long term impacts of urban runoff on stream water quality and biota,
4. To develop empirical relationships that will allow data from the two study areas to be transferred to other similar areas,
5. To develop practical best management practices and concepts that can be applied to the specific study areas, similar urban areas, and urbanizing areas.

MARC Objectives

In addition to the national EPA objectives of the NURP program, MARC has a number of objectives relative to its role as the 208 Water Quality Planning Agency for the Kansas City Metropolitan Region. Planning under Section 208 of the Water Pollution Control Act considered a number of issues related to wastewater treatment, including nonpoint source pollution data collection needs, and concluded that better pollution loading and runoff characteristic data from nonpoint sources were needed to prepare specific nonpoint analyses and recommendations.

During preparation of the 208 Water Quality Management Plan, no actual monitoring of nonpoint source pollution was performed. A mathematical model was employed to estimate nonpoint pollution loads by relating land use to potential pollutants from land use sources. These theoretical values indicate the potential impact of urban runoff on streams in the Kansas City area. This modeling effort identified sediment as the predominant pollutant in both weight and concentration in stormwater runoff. The conclusion of the 208 plan was that while nonpoint source pollution is a significant contributor of pollutants to streams in the region, its impact is not great enough to cause stream quality violations on an areawide basis. Thus, one MARC objective is to use the pollutant loading data generated in the NURP study as a check on the estimated loadings generated in the 208 study.

A second MARC objective relates to a model ordinance developed by MARC; the Model Grading and Sediment Control Ordinance. The need for this ordinance and the appropriateness of the methodology it employs were considered in light of the NURP study data.

City of Independence NURP Objectives

Specific objectives of the City of Independence were to: (1) develop transfer coefficients and methodologies for urban runoff so that runoff data and characteristics from Rock Creek and Indian Creek can be transferred to the total City of Independence area; (2) calculate the hydrological characteristics of urban runoff for stormwater control; (3) aid in the development of innovative stormwater runoff control methods that can be used in the City of Independence; and (4) aid in the development of a draft stormwater control manual that can be used in the City of Independence to control urban runoff problems.

Johnson County NURP Objectives

Johnson County presently has a strong water quality monitoring program in the Indian Creek watershed, especially in the measurement of benthic macroinvertebrates. The specific objectives of Johnson County, in addition to those of EPA, were to: (1) determine the cause of observed stressed conditions in Indian Creek; and (2) provide data and results that can be used by Johnson County personnel in managing water quality in Indian Creek.

The MARC NURP study was designed to provide the following information:

1. the nature of urban runoff problems
2. the severity of these problems
3. the causes of these problems
4. the opportunities for controlling urban runoff problems.

Results of the program may require a re-examination of the adequacy of current dry-weather water quality standards, especially in judging the significance of storm-dominated pollution problems.

1.1.2 PROJECT DESIGN

The NURP project was designed to meet these nationwide, areawide, and local objectives by operating an automated water quality monitoring system. Two area creeks, one in each of the local participants' jurisdiction, were selected for monitoring (Figure 1.1). The Johnson County Unified Wastewater Districts (JCUWD) provided field crews, laboratory facilities and personnel, and administrative support for the monitoring of Indian Creek in northeastern Johnson County, Kansas. The

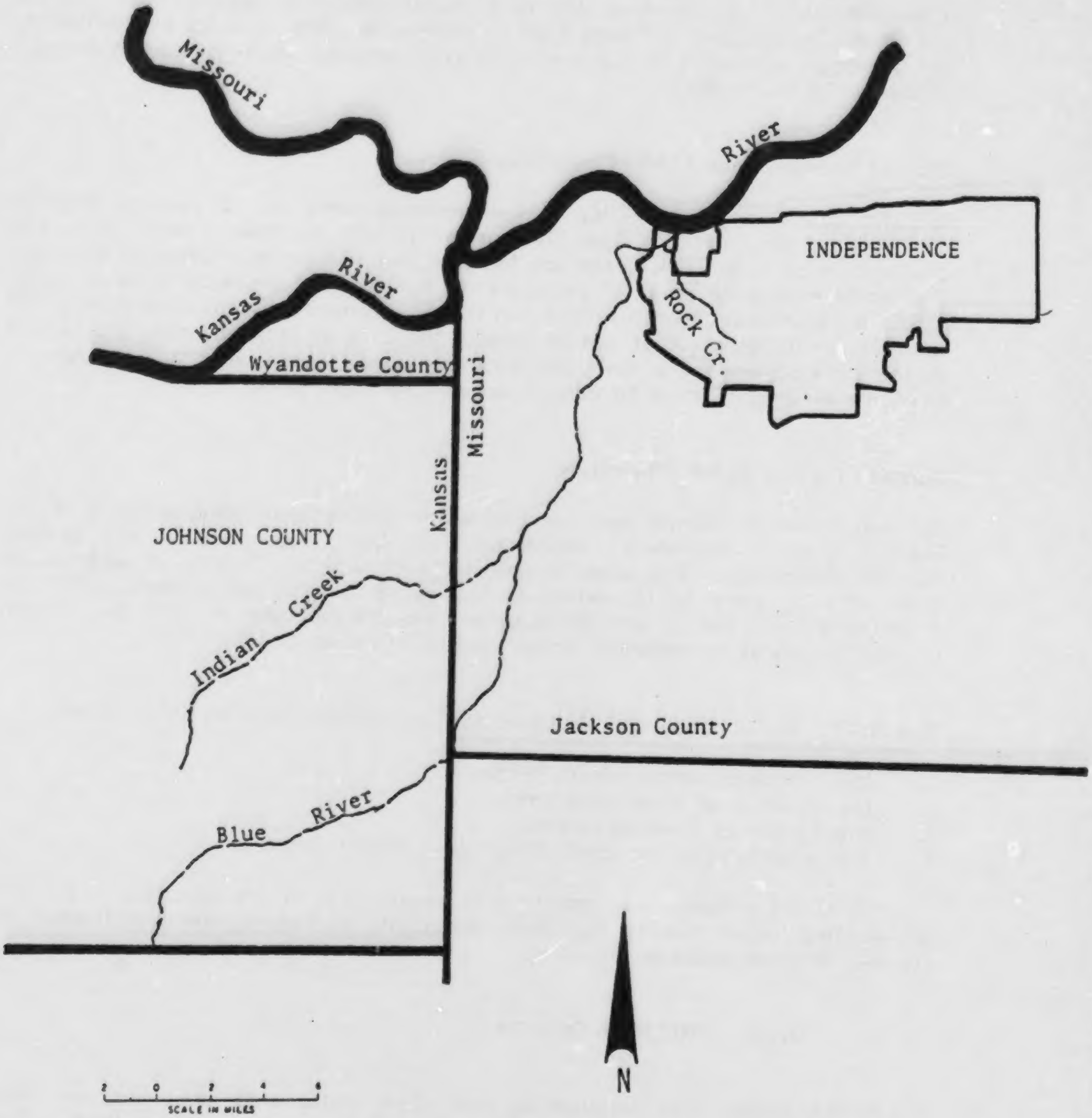
Missouri
River
Kansas
River
Wyandotte County
Kansas
Missouri
INDEPENDENCE
Rock Cr.
JOHNSON COUNTY
Indian
Creek
Jackson County
Blue
River
N
2 0 2 4 6
SCALE IN MILES

FIGURE 1-1

KANSAS CITY NURP STUDY AREAS: INDIAN CREEK AND ROCK CREE

City of Independence supplied similar services for the monitoring of Rock Creek in western Independence, Missouri. In addition, the JCUWD assumed responsibility for the analysis of both study areas' heavy metals samples while Independence supplied the installation housings for each monitoring site.

The two study areas were administered and operated separately. MARC performed the administrative functions of the NURP project, coordinating all the different groups and the disbursement of project funds. Public participation activities were also handled by MARC.

The technical consultant, F.X. Browne Associates, Inc., provided the engineering design, participant training, quality control, and day to day technical management of the monitoring program. In addition, the analysis of the data, the encoding of the data to EPA requirements, and the preparation of the final report were performed by the consultant. This report reviews the project design, the monitoring and data analysis methods, and discusses the findings from the monitoring data.

The monitoring stations were designed and installed to automatically collect and record runoff flow and rainfall data. In addition, the monitoring equipment was linked together to collect runoff samples in a calculated fashion in order to produce one composite sample representing a site's average runoff water quality. During the study, over twenty different storm events were sampled, ranging from less than .25" to over 3.00" of rain. Other sampling was performed in dry weather, and immediately after storms to determine how quickly stream water quality returned to dry weather conditions.

A benthic organism survey was conducted on Indian Creek to link the water quality data with the impact on the aquatic community. A special toxic pollutant survey was also performed to determine if EPA's priority pollutants were found in Kansas City area urban runoff.

Two types of monitoring sites were installed in both study areas. Small catchments (all less than 100 acres) of relatively homogeneous land use were monitored as one type. One commercial and one residential area were studied in both areas, and a light industrial catchment was included in the Indian Creek study area.

These land use sites were designed to provide specific land use concentration and loading data for EPA's nationwide NURP effort. The data from these sites are being used to determine one major unknown in the nonpoint source problem, the actual pollutant loadings (usually expressed in pounds/acre/year) that are generated from different types of land uses. Pollutant loading rates for specific land uses can be transferred to other areas with similar land usage and characteristics to estimate pollutant loads. The transferable pollutant loading data can be used by local agencies to analyze unique impacts of urban runoff, without the need for extensive (and expensive) site specific monitoring.

For the Kansas City area study, monitoring sites were installed on larger natural creeks draining watersheds from 1372 to 23,942 acres. These sites were designed for specific local and areawide purposes. In Johnson County, the NURP stream data acquisition program was designed to determine the causes of stressed benthic populations and to augment the JCUWD's database and understanding of the creek's water quality processes. Independence stream monitoring was geared more to stormwater management issues such as runoff rates and erosion. MARC planned to use the stream data to verify and refine estimated loadings developed in the MARC Section 208 Areawide Water Quality Plan.

The data generated from both types of stations were similar. Each of the fourteen stations were monitored for an average of 15 storms. For each station and storm the following types of data were collected·

Runoff Flow - 5 parameters
Precipitation - 6 parameters
Runoff Sample Pollutant Concentrations - 29 parameters

Much of the data were reduced from strip charts recording flow or rainfall. Refined data was recorded and then entered into the Johnson County Data Services IBM mainframe computer, where the SPSS computer package was used for data storage and manipulation. The SPSS package was used to encode the data set into the format required for the EPA's nationwide computer system. Finally SPSS data files were used with a City of Independence microcomputer to employ statistical techniques for the characterization of the concentration and pollutant loading data. The effects of hydrologic, geologic, and especially land use factors were the key elements in this task.

This final report outlines the methods used and the main findings of the Kansas City area NURP project. The actual data are listed in a separate appendix.

1.2 DESCRIPTION OF STUDY AREA

1.2.1 208 PLANNING AREA

The planning area for MARC's 208 water quality planning program includes Cass, Clay, Jackson, Platte and Ray Counties in Missouri and Johnson, Leavenworth, and Wyandotte Counties in Kansas.

The Kansas City Metropolitan Region (KCMR), located at the confluence of the Missouri and Kansas Rivers, has grown from a small fur-trading settlement to a sprawling metropolitan region that is home to more than 1.3 million people. The area covers nearly 4,000 square miles.

Until the end of World War II, most development in the KCMR occurred within a semi-circular core area south of the Missouri River that includes the central business districts of the two Kansas Citys. At this time, the core area was the most dominant sector. In recent decades, however, most development has occurred outward from the core and along major transportation corridors. Freeway access and annexations by local governments, which provide urban services and facilities, have encouraged this suburban development.

Residential development occupied more than 54% of the acres in urban use in 1973. The predominant residential use is the single-family dwelling.

Commercial activity is increasing in suburban areas as regional shopping centers have been developed at highway interchanges in outlying areas of the region. As a result, much retail activity has shifted from the core to outlying retail centers.

Jackson and Johnson Counties have the greatest number of acres in industrial use. The major areas of recent industrial development are the Little Blue Valley in Jackson County, the Lenexa/Olathe/Interstate Highway 35 corridor in Johnson County, and the Kansas City International Airport area in Platte County.

The topography, soils and water resources of the region are the most significant aspects of the region's physical environment. A large portion of the region is composed of gently rolling hills with elevation ranging from 690 feet to 1200 feet. There are numerous areas of steep slopes and low-lying floodplains, where care must be taken if development is to occur. The presence of these physical factors indicates that erosion and flooding are likely to occur in many areas.

Soil properties common to the region also require developers to take precautions. Perhaps the most significant aspect of the regional soil profile is that approximately 80 percent of the region's soils are not well suited for septic tank effluent absorption. As a result, septic tanks cause water quality and health problems.

The surface water resources of the region are most impressive. Within the region, numerous creeks and streams drain into the Missouri and Kansas Rivers. In addition, there are eleven major man-made lakes of fifty surface acres or larger. These surface waters provide recreational opportunities and water supply for the KCMR.

An analysis of regional rainfall indicates that the region averages over one hundred rain events per year and the average volume of precipitation delivered per event ranges from .17 inches in January to .50 inches in July. Average rainfall intensities range from .02 inches per hour in January to .12 inches per hour in July. Hourly rainfalls of one inch or greater are common.

1.2.2 INDIAN CREEK STUDY AREA

Indian Creek in Johnson County originates near Olathe and flows past the urbanizing area of Lenexa and Overland Park into the Blue River (see Figure 1.2). Indian Creek drains one of the most rapidly developing areas in the region. Slopes range from mild to moderate. Land use ranges from low to high density residential, shopping centers and light industrial.

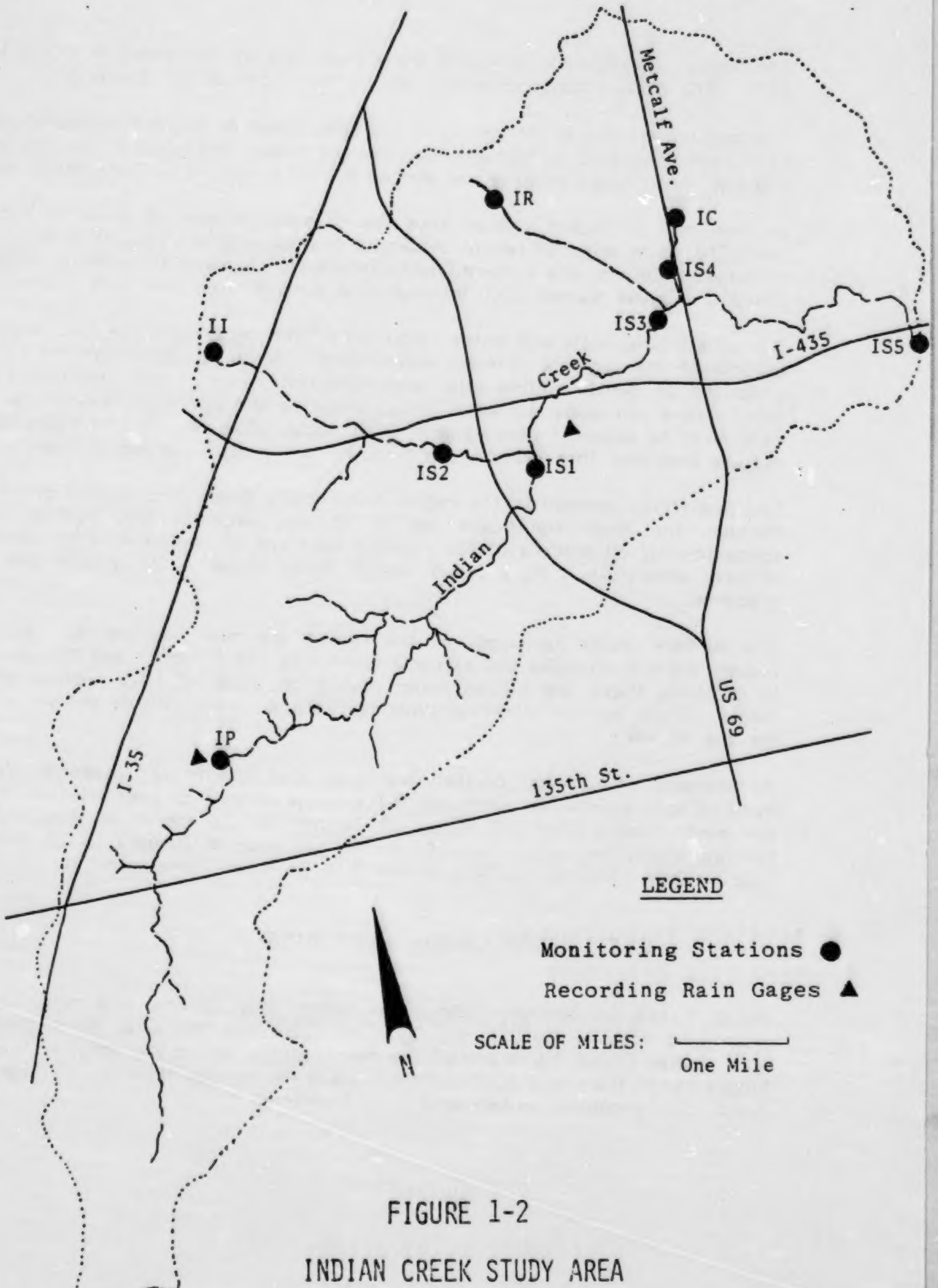
Metcalf Ave.
IR
IC
IS4
IS3
II
I-435
IS5
Creek
IS2
IS1
Indian
US 69
IP
I-35
135th St.
LEGEND
Monitoring Stations ●
Recording Rain Gages ▲
SCALE OF MILES:
One Mile
N

FIGURE 1-2

INDIAN CREEK STUDY AREA

1.2.3 ROCK CREEK STUDY AREA

Rock Creek in the City of Independence (Jackson County) forms its headwaters in southwest Independence and flows north into the Missouri River just below the mouth of the Blue River (see Figure 1.3). Rock Creek drains an area of 9.2 square miles in the southwest and west parts of Independence. Rock Creek has many small tributaries. It has an average channel width of 30 feet, and an average slope of 50 feet per mile. The watershed contains moderate to steep slopes, resulting in frequent flooding of urban areas adjacent to the Creek.

The study area has a mean annual rainfall of 40.64 inches. Land use is primarily low to medium density residential and strip commercial.

1.2.4 STATION LAND USE SUMMARY

A wide range of watershed size and land use were monitored during the NURP study. Each of the five land use stations represents a specific land use type. The five Indian Creek stream stations generally represent a large stream and tributaries that are more heavily influenced by urbanization as one travels downstream. The three Rock Creek stream stations drained heavily urbanized areas constructed on steep slopes. A land use summary of each site follows.

Land Use Sites (Table 1.1)

II (Indian Industrial): A 72 acre light industrial area; slightly over half of the basin is developed.

IC (Indian Commercial): A 58 acre shopping mall with 93% of the drainage surface impervious concrete or roofs.

IR (Indian Residential): A 63 acre medium density residential area drained by concrete curb and gutter system connected to storm sewers.

RC (Rock Commercial): A 36 acre half strip commercial, half medium density residential basin.

RR (Rock Residential): A 58 acre medium density residential area drained mostly by swales.

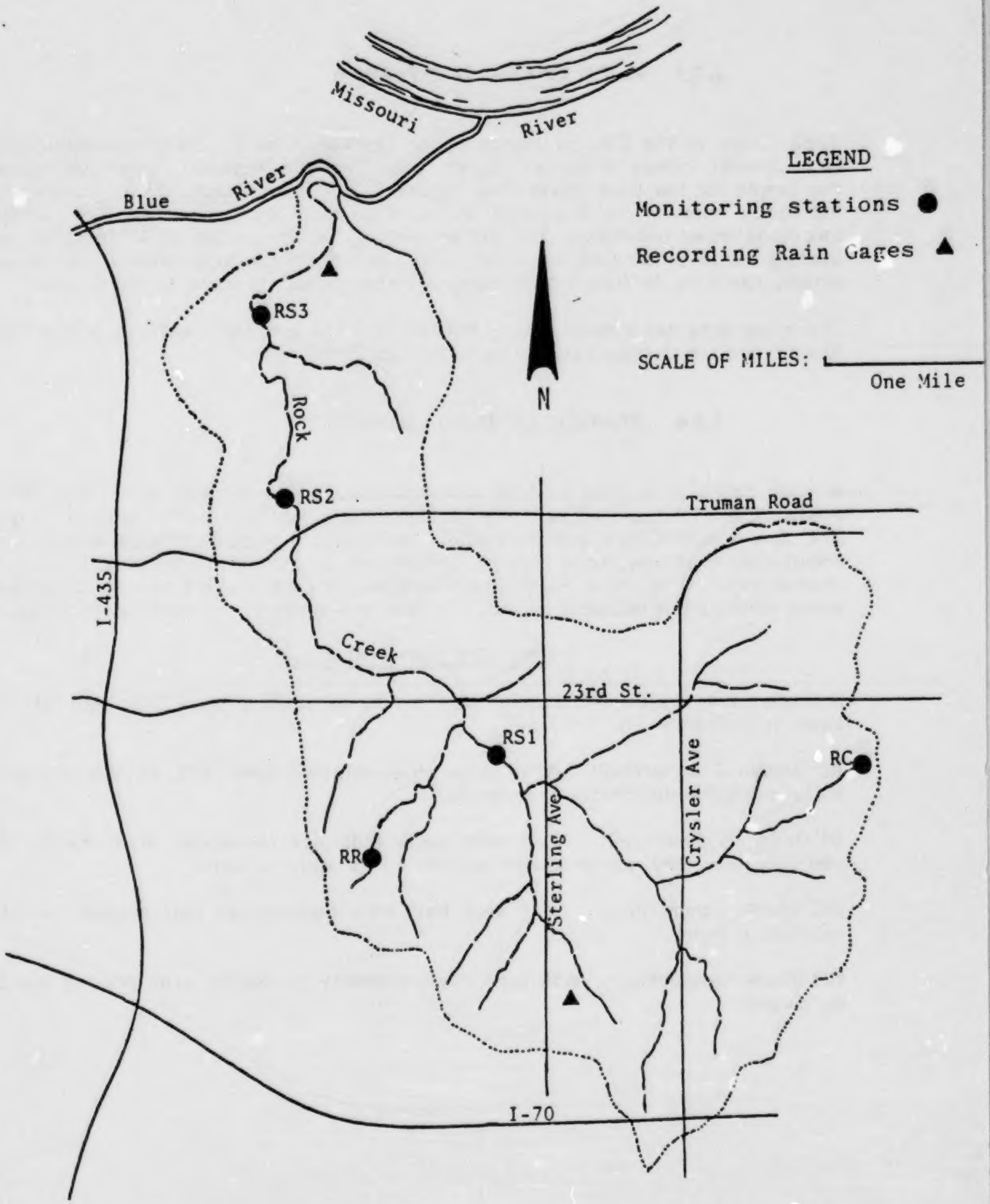
Missouri River
Blue River
LEGEND
Monitoring stations ●
Recording Rain Gages ▲
SCALE OF MILES:
One Mile
N
RS3
Rock
RS2
Truman Road
I-435
Creek
23rd St.
RS1
RC
RR
Sterling Ave
Crysler Ave
I-70

FIGURE 1-3

ROCK CREEK STUDY AREA

Rock Creek Stream Stations

RS1 ("Rock Stream 1"; Upstream Station): A 3,045 acre area, mostly residential; about 17% open land.

RS2 (Middle Station): A 4,624 acre basin with similar land use to RS1.

RS3 (Downstream Station): A 5,566 acre basin, mostly residential with 21% open land.

Indian Creek Stream Stations

IS1 (Upstream Main Channel Station): An 11,005 acre mixed land use basin, 52% developed; includes significant agricultural acreage.

IS2 (Upstream Tributary): A 3,691 acre mixed land use basin, 84% developed.

IS3 (Middle Main Channel Station): A 16,862 acre mixed land use basin with more urban area; 63% developed.

IS4 (Downstream Tributary): A 1,372 acre, 77% developed mixed land use basin.

IS5 (Downstream Main Channel Station): A 23,941 acre mixed land use basin draining large urban areas in Johnson County; 69% developed.

Tabie 1.1 Land Use Data
Indian Creek

Land Use Parameter	Units	IS1	IS2	IS3	IS4	IS5	IC	II	IR
Agriculture	acres	2400	0	2400	0	2500	0	0	0
Low Density Residential	acres	2400	750	3600	80	4550	0	0	6
Medium Density Residential	acres	2360	1300	4700	652	8911	0	0	50
High Density Residential	acres	150	100	300	50	450	0	0	2
Office	acres	70	100	400	70	600	0	0	0
Commercial	acres	300	300	600	200	1000	56	0	0
Public	acres	240	55	330	50	560	0	0	0
Parkland	acres	550	75	842	25	1250	0	0	0
Vacant	acres	1900	300	2200	200	2500	2.4	32	5
Construction	acres	160	140	440	35	570	0	0	0
Area Total	acres	11,005	3691	16,862	1372	23,941	58	72	63
Impervious Area	%	25	42	30	41	32	97	44	37
Latitude	°,',"	99 41 53	94 42 19	94 40 25	94 40 04	94 37 54	94 40 02	94 44 43	94 41 48
Longitude	°,',"	38 55 34	38 55 46	38 56 27	38 56 47	38 55 52	38 57 05	38 56 53	38 57 44
Slope of Drainage Basin	ft./mile	180	235	180	180	170	105	150	230
Slope of Drainage Channel	ft./mile	15	30	15	60	14	45	42	132
Length of Main Channel	feet	64,056	17,836	77,340	11,590	93,301	2083*	376*	347†
Portion of Area w/Storm Sewers	%	40	80	60	90	70	100	90	90
Portion of Streets w/Swales	%	60	20	40	20	30	10	20	20
Portion of Streets w/Curbs	%	40	80	60	80	70	90	80	80
Hydrologic Soil Group B %		39	64	41	73	48	89	45	83
Hydrologic Soil Group C %		51	35	52	27	46	11	55	17
Hydrologic Soil Group D %		10	1	7	0	6	0	0	0
Available Water Capacity	in H_2O/ in. Soil	.21	.22	.21	.23	.22	.23	.22	.23
Soil Permeability	in./hr.	1.11	1.22	1.13	1.25	1.15	1.28	1.20	1.27

* concrete pipe

† concrete channel

		Rock Creek				
	Units	RS1	RS2	RS3	RC	RR
Agriculture	acres	0	0	0	0	0
Low Density Residential	acres	0	0	0	0	0
Medium Density Residential	acres	2,271	3,435	4,027	18	58
High Density Residential	acres	0	0	0	0	0
Commercial	acres	152	206	244	18	0
Industrial	acres	98	100	100	0	0
Parkland	acres	116	305	414	0	0
Vacant	acres	397	567	760	0	0
Construction	acres	11	11	11	0	0
Area Total	acres	3,045	4,624	5,566	36	58
Impervious Area	%	36.5	36	35	68	38
Latitude	°,′,″	94 27 03	94 28 13	94 28 19	94 24 50	94 27 56
Longitude	°,′,″	39 04 36	39 06 06	93 06 43	39 04 25	39 04 05
Slope of Drainage Basin	ft./mile	240	255	265	132	296
Slope of Drainage Channel	ft./mile	65	50	44	128	160
Length of Main Channel	feet	14,020	27,426	32,433	0	760
Portion of Area w/Storm Sewers	%	.6	.5	.5	50	0
Portion of Streets w/Swales	%	98	98	98	50	89
Portion of Streets w/Curbs	%	2	2	2	50	11
Hydrologic Soil Group B	%	100	100	100	100	100
Hydrologic Soil Group C	%	0	0	0	0	0
Hydrologic Soil Group D	%	0	0	0	0	0
Available Water Capacity	in H_2O/ in. Soil	.21	.21	.21	.21	
Soil Permeability	in./hr.	1.3	1.3	1.3	1.3	1.3

1.3 MONITORING METHODS

The basic storm sampling procedure was to automatically collect constant volume, variable interval, flow composited samples. Each storm produced one sample representing the average pollutant concentration of the entire amount of storm runoff. The pollutant concentrations measured by the laboratories were equivalent to event mean concentrations (EMC's). The number of storms sampled for each station is detailed in Table 3.7 (page 3-15).

Several other sampling programs were conducted in addition to stormwater sampling. Low flow and post storm samples were composites of three or four manually collected grab samples. The limited number of wetfall/dryfall samples were collected in buckets that were changed manually from dryfall collection to precipitation collection. Field data (DO, temperature, pH) and microbial grab samples were collected whenever field crews were on the scene during rain events. Several priority pollutant samples were collected as grab samples for several storms.

1.3.1 RUNOFF QUANTITY

ISCO model 1870 flowmeters were used at each site to measure flow. These flowmeters used a bubble system to measure water level which was then converted electronically to record discharge (flowrate) in cubic feet per second (cfs).

The conversion between water level and flowrate was achieved by programming a Programmable Read Only Memory (PROM) with a stage-discharge table. These tables were developed for each site from one of two sources: stream gaging and primary devices.

Each direct runoff station (II, IC, IR, RC, and RR) was equipped with a specific primary device, such as a flume or weir, which was designed to register a unique depth (stage) for each discharge rate. Stage-discharge tables are printed in the literature for different types and sizes of primary devices.

The remainder of the stations experienced flows higher than most primary devices could accept. Stable stream reaches with suitable hydraulic characteristics were selected near each station, and manual measurement of the stage-discharge relationships was performed.

Price current meters were used to gage stream discharge, and the corresponding stage was measured for each gaging. Each site required 5-10 gagings at different flow levels to develop a stage discharge relationship. Extrapolation techniques were used for low flow and high flow values outside the measured range.

Descriptions of the flowmetering techniques for each station are in section 1.3.5.

1.3.2 RUNOFF QUALITY

Storm runoff was collected by a Sigmamotor 6210 fast-flo pump sampler. Constant volume-variable interval samples were composited into two and one half gallon plastic jugs. Individual sample aliquot volumes at each site were determined by the lowest sample pump time that would deliver at least 150 ml; this value represented the minimum reproduceable sample volume for an average station.

The interval between individual sample aliquots was determined by the total runoff volume recorded by the flowmeter. The flowmeter sent electronic pulses after a pre-set runoff volume had been recorded; this triggered collection of an individual sample aliquot by the sampler. During high flows the sampling frequency was rapid, and in some cases almost continuous; for low storm flows, sampling intervals of several hours often occurred. The sampling intervals were changed frequently throughout the course of the study to reflect the anticipated size of storm, the presence of multiple overflow buckets, and the application of more accurate runoff data.

The sampler system was designed to remain dormant during low flow periods. Stream stations were equipped with float activation switches connected in the flowmeter sampler pulse circuit. The switches were manually set at least every week to reflect seasonal or even temporary low flow conditions.

Each PROM could be programmed with four stage-discharge relations. Most stream stations were equipped with three modified stage-discharge relations on the PROM to serve as a backup for temporary activation switch failures. The low flow end of the stage-discharge curve was changed to register zero flow for average base flow conditions; flow was not recorded until the storm flow reached a depth above the designated base flow level. This backup was used less than 10% of the time at most stations.

Station locations were designed to keep in-line sample velocity at a minimum of three feet per second. Sigmamotor performance curves of head versus sample velocity indicated fourteen feet was the maximum allowable head. All stations were within this limitation.

The in-stream sampling apparatus at most sites consisted of standard Sigmamotor 12 inch sample strainers with one-quarter inch holes. The general location of the strainers was in the main flow section of the stream and at least one third of the way above the bottom during a typical small storm event. Most of the strainers were placed vertically.

Two cross-sectional concentration analyses were performed during small storm events at all stream stations to determine the variability across the stream and as a function of depth. No specific patterns were determined due to the large variability in the data. Generally, the concentrations in the main channel areas did seem to be the most representative of the average flow concentrations. Higher concentrations of suspended solids were found at lower depth, as could be expected. Most of the stream stations appeared very well mixed across the surface during medium to large storm events, suggesting that depth of sampler intake is probably the most sensitive factor.

1.3.3 PRECIPITATION MONITORING

Both automatic tipping bucket recording raingages and total precipitation collectors were used. Four Texas Electronics, Inc. Model R2-1014P tipping bucket raingages were installed (two in each study area) to collect rainfall intensity, rainfall duration, and duration between storm data. The volume recorder was accurate to ±.01", and the chart speed indicating the storm timing data was accurate to ±20% without adjustment. Weekly markings on the raingage strip chart allowed interpolating between real times and probably reduced this uncertainty to around 5%. The raingages were mounted on roofs at these locations:

Station IP	Olathe, Kansas
Corporate Woods Maintenance Building	Overland Park, Kansas
Rock Creek Treatment Plant	Independence, Missouri
Fire Station 5	Independence Missouri

Weathertronics 11" plastic raingages were chosen to collect additional total precipitation data to ±.01". These raingages were usually mounted inside the station housings with the collection funnel on the roof. A tube running through the roof connected the collector to the recording cylinder. These raingages were checked at least once a week; in addition they were generally read and emptied after a storm event.

1.3.4 ATMOSPHERIC SAMPLING

An abbreviated sampling program was conducted because automatic wetfall/dryfall samplers on order were never delivered. Large potato salad buckets corresponding to the EPA recommended size were installed at two locations. Initially, a manual exchange between dryfall collection bucket and a rainfall collector was attempted at one site. This proved impractical, and eventually both sites were utilized as monthly bulkfall samplers. Only a few samples were analyzed.

1.3.5 MONITORING STATION DESCRIPTIONS

Station IS1 Description

Stream	Indian Creek (Middle Basin)
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	111th and Indian Creek Parkway
Description	Housing at 21' east of the west end and 36' south of the eastbound lane of 111th St.
Basin Size	11,005 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/roof housing
Type of Channel Near Intake	Natural stream channel downstream of rock ledge; rock debris and gravel on bottom under shallow silt layer.
Stage Discharge Relationship	Stream Rating
June 1981 to August 21, 1981	Rating 1
Lowest gaged point	2.5 cfs
Highest gaged point	304 cfs
Extrapolated to	2400 cfs (semi-log)
Accuracy	fair
August 21, 1981 to Dec. 1981	Rating 2
Lowest gaged point	3.7 cfs
Highest gaged point	447 cfs
Extrapolated to	1990 cfs (semi-log)
Accuracy	good
April 1982 to October 31, 1982	Rating 3
Lowest gaged point	4.9 cfs
Highest gaged point	304 cfs
Extrapolated to	494 cfs (curve extension)
Accuracy	good

Notes:

1. Rating 3 PROM installed June 23, 1982; prior storm hydrographs calculated manually from water level data. Discrete time composite samples were composited using a volume to flowrate ratio technique.
2. Low flow rating affected by August 13, 1982 flood.

Station IS2 Description

Stream	North Branch of Indian Creek
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	Near Switzer Rd. & 111th St.
Description	Housing directly on box culvert on south side of creek between Switzer and Hwy. 69 Alternate.
Basin Size	3,691 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/roof housing
Type of Channel Near Intake	Natural stream channel with eroding sides; some removal of natural vegetation near station.
Stage Discharge Relation	Stream Rating
April 1, 1982 to August 13, 1982	Rating 1
Lowest gaged point	1.4 cfs
Highest gaged point	228 cfs
Extrapolated to	499 cfs (Manning's Equation)
Accuracy	good

Notes:

1. A dam across the stream related to downstream construction activities was built in May 1981 just downstream of Hwy. 69 Alternate bridges. No equipment was installed due to high water in the housing during large storm events. Stream gaging of the undammed stream began in March 1982.

2. PROM installed 6/15/82; prior storm hydrographs calculated manually from water level data. Discrete time composite samples were composited using a volume to flowrate ratio technique.

3. Station shut down after August 13, 1982 flood.

Station IS3 Description

Stream	Indian Creek
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	Near Marty Rd. and 95th St.
Description	Housing at 320' west of Marty Rd. and 63' south of sanitary sewer line in trace C of Indian Creek Park. The housing is right along the park tree line of the stream.
Basin Size	16,862 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	None
Type of Channel Near Intake	Natural stream channel with smooth hard rock bottom; no sediment except near stream banks.
Stage Discharge Relation	USGS Stream Ratings
June 1981 to October 6, 1981	Rating 1 USGS Rating 27: May 24, 1978 to September 1980
Lowest gaged point	.7 cfs
Highest gaged point	455 cfs
Extrapolated to	2550 cfs (USGS extrapolated)
Accuracy	fair
October 6, 1981 to December, 1981	Rating 2 USGS Rating 28
Lowest gaged point	0 cfs
Highest gaged point	520 cfs
Extrapolated to	1980 cfs
Accuracy	good
April 1982 to October 31, 1982	Rating 3: NURP Rating and USGS Rating 28
Lowest gaged point	8.4 cfs
Highest gaged point	42 cfs (see notes)
Extrapolated to	1980 cfs
Accuracy	good

Notes:

1. Up to .6' of datum shift occurred during the NURP study. The shifts had the most impact at low flow. Rating 3 intersected Rating 2 at about 100 cfs; thus Rating 3's highest gaged point could be considered Rating 2's 520 cfs.
2. Rating 3 PROM was installed May 15, 1982; prior storm hydrographs calculated manually from water level data. Discrete time composite samples were composited using a volume to flowrate ratio technique.
3. Low flow rating probably was affected by August 13, 1982 flood.

Station IS4 Description

Stream	Unnamed Indian Creek tributary
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	9929 Metcalf near Floyd Dr.
Description	Housing 105' north of Floyd Dr. on edge of Atonement Lutheran Church parking lot
Basin Size	1,372 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/roof of housing
Type of Channel Near Intake	Natural stream channel with gravel and rock bottom. Housing 30 yds. upstream of three 12x8 box culverts; two with 1-2' of rock and sediment on floor
Stream Discharge Relation	Stream Ratings
June 1981 to December 1981	Rating 1
Lowest gaged point	.2 cfs
Highest gaged point	58 cfs
Extrapolated to	920 cfs (culvert equations)
Accuracy	fair
April 1982 to August 13, 1982	Rating 2
Lowest gaged point	.41 cfs
Highest gaged point	75.6 cfs
Extrapolated to	816 cfs (Manning's Equation)
Accuracy	good

Notes:

1. Rating 2 PROM installed June 10, 1982; prior storm hydrographs calculated manually from water level data. Discrete time composite samples were composited using a volume to flowrate technique.
2. Station shut down after August 13, 1982 flood.

Station IS5 Description

Stream	Indian Creek
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	Mission Rd. in Fox Hill Park
Description	Housing about 100' upstream from northwest corner of bridge on south side of creek.
Basin Size	23,942 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/On road to Indian Creek Sewage Treatment Plant, ½ mile away
Type of Channel Near Intake	Natural stream channel with 2-3' thick sediment deposits over rock bottom. Station located on pool 3-4' deep upstream of riffle under Mission Rd. bridge.
Stage Discharge Relationship	Stream Ratings
June 1981 to August 21, 1981	Rating 1
Lowest gaged point	11.5 cfs
Highest gaged point	487 cfs
Extrapolated to	2250 cfs (semi-log)
Accuracy	fair
August 21, 1981 to October 31, 1982	Rating 2
Lowest gaged point	8.9 cfs
Highest gaged point	1350 cfs
Extrapolated to	1420 cfs (curve extension)
Accuracy	good

Notes:

1. Flow below 300 cfs registered by Rating 1 were adjusted to reflect Rating 2 data.
2. Low flow rating affected by August 13, 1982 flood.

Station RS1 Description

Stream	Rock Creek
Location - City	Independence
County/State	Jackson County, Missouri
Street	Northern and Ayers
Description	Housing is on east side (upstream side) of Northern Blvd. on south side of Rock Creek. Housing is next to old USGS equipment housing which was removed August 1982.
Basin Size	3,045 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	None
Type of Channel Near Intake	Natural stream channel with 1' of sediment on rock floor. Sewer line-weir and bridge wing-walls create pond 2-3' deep above bridge. Sides eroding on north side of channel.
Stage Discharge Relationship	Rating of flow over sewer line approximately a 38' broadcrested weir
June 1981 to July 20, 1982	Rating 1: USGS supplied Rating verified at 6 and 35 cfs
Highest point on rating	1760 cfs; fair to good to 50 cfs; poor above 50 cfs
July 20, 1982 to August 13, 1982	Rating 2 USGS modified rating
Highest gaged point	214 cfs
Extrapolated to	991 cfs
Accuracy	fair

Notes:

1. Rating 1 flows were adjusted to reflect the Rating 2 gaging data.
2. Some leakage occurred under the sewer line.
3. Station shut down after August 13, 1982 flood.

Station RS2 Description

Stream	Rock Creek
Location - City	Independence
County/State	Jackson County, Missouri
Street	Mt. Washington Cemetery between Hwy. 24 and Truman Rd.
Description	Housing is on south side (upstream side) of road embankment near Rock Creek culvert.
Basin Size	4,624 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/On stake 10 yds. from housing (removed by vandals during some portions of study).
Type of Channel Near Intake	Natural stream channel upstream with shallow 1-2' pool with rock and some sediment on bottom. No major bank erosion. Culvert is 8' high x 14' CMP arch pipe.
Stage Discharge Relationship	Stream Ratings
June 1981 to December 1981	Rating 1
Lowest gaged point	.63 cfs
Highest gaged point	54 cfs
Extrapolated to	937 cfs (Manning's Equation)
Accuracy	poor
April 1982 to October 31, 1982	Rating 2
Lowest gaged point	.53 cfs
Highest gaged point	384 cfs
Extrapolated to	556 cfs (Manning's Equation)
Accuracy	fair

Notes:

1. No high gagings (greater than 54 cfs) were actually performed on site because of very swift water through the arch pipe and the lack of a place to drop cable gaging equipment. In May and June of 1982, a bridge in Mt. Washington cemetery was used for rating the RS2 arch pipe. The bridge was .50 river miles downstream of RS2 and .89 river miles upstream of RS3.

The basin areas draining to this bridge, compared to RS2 and RS3, were:

RS2	4624
Alternate gaging bridge	5017
RS3	5566

Hydrographs were compared between RS2 and RS3 and an adjustment flow factor was used to approximate RS2 flows from gaged flows at the downstream bridge. These data were used to develop Rating 2.

2. Rating 1 flows were adjusted to reflect the Rating 2 gaging data.

3. Rating 2 PROM installed July 20, 1982; prior storm hydrographs calculated manually from water level data. Discrete time composite samples were composited using a volume to flowrate technique.

Station RS3 Description

Stream	Rock Creek
Location - City	Independence
County/State	Jackson County, Missouri
Street	Kentucky Rd. between Rock Creek Rd. and Hillcrest
Description	Flow measuring station 100 yds. downstream of bridge on top of streambank. Sampling station directly under east side of bridge.
Basin Size	5,566 acres
Flowmeter	0-12' ISCO 1870
Raingage Type/Location	Total volume/on stake 30 yds. away inside pump station fence
Type of Channel Near Intake	Natural stream channel; 1-2' sediment over rock floor. Railroad trestle 50 yds. upstream restricts flow with hung-up trash and debris. Gunnite and rock wall is built on northeast side of channel from sampler intake to flow-meter bubbler. Low flow channel subject to change after large storms.
Stage Discharge Relationship	Stream Ratings
June 1, 1981 to July 20, 1982	Rating 1
Lowest gaged point	.5 cfs
Highest gaged point	250 cfs
Extrapolated to	1463 cfs (semi-log)
Accuracy	poor above 140 cfs; fair under 140 cfs
July 20, 1982 to August 13, 1982	Rating 2
Lowest gaged point	1.8 cfs
Highest gaged point	355 cfs
Extrapolated to	1930 cfs (Manning's Equation)
Accuracy	fair

Notes:

1. High flows above 140 cfs registered by Rating 1 were adjusted to reflect Rating 2 gaging data; the highest gaged point of rating one (250 cfs) was considered in error.

2. Station closed down after August 13, 1982 flood.

Station IC Description

Stream	Storm sewer draining Metcalf South Shopping Center
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	Near Travis and 97th Terrace
Description	Housing sits on 4x12 concrete box culvert on southwest corner of Metcalf South Shopping Center near Metcalf. Housing is 14' north and 29' west of the corner of Travis Lane and 97th Terrace.
Basin Size	58 acres
Flowmeter	0-6' ISCO 1870
Raingage Type/Location	Total volume/roof of housing
Type of Channel Near Intake	Concrete culvert floor near junction of one short 36" RCP draining concrete highway drainage channel, one 36" RCP draining west side of mall, one 42" RCP draining east side of mall.
Stage Discharge Relationship	Primary Device: Plywood cutthroat flume, 2' tall, 9' long, and 5.6' throat. Flume attached to end of 16' approach box downsream of 4' tall x 8 box culvert.
Peak Assured Accurate Flow	59.8 cfs
Maximum Flow on Rating	145 cfs (sideweir approximation)

Station II Description

Stream	Upper tributary of North Branch of Indian Creek
Location - City	Lenexa
County/State	Johnson County, Kansas
Street	Between 9901 & 9939 Widmer Rd.
Description	Housing sits near 6' RCP drainage pipe 375' east of Widmer Rd. between Shasta Bottling (9901 Widmer) and Hoover International (9939 Widmer).
Basin Size	72 acres
Flowmeter	0-6' ISCO 1870
Raingage/Location	Total volume/roof of housing
Type of Channel Near Intake	6' RCP
Stage Discharge Relationship	Primary Devices:
June 1980 to April 18982	Rating 1 "Dewinged" poured concrete Palmer-Bowlus flume at end of 6' RCP.
Peak Assured Accurate Flow	10 cfs
Highest Flow on Rating	278 cfs
April 1982 to June 23, 1982	Rating 2 Plywood cutthroat flume, 2' tall, 4.5' long, 1.5' throat. Flume attached on top of old dewinged Palmer-Bowlus flume near end of 6' RCP.
Peak Assured Accurate Flow	19.8 cfs
Highest Flow in Rating	19.8 cfs
June 23, 1982 to August 31, 1982	Rating 3 Plywood cutthroat flume (same as Rating 2)

Peak Assured Accurate Flow	19.8 cfs
Highest Flow on Rating	144 cfs (broadcrested weir approximation)

Notes:

1. Poured "Dewinged" Palmer-Bowlus flume dimensions: 6' long flat surface middle section, 1' deep above pipe center line, 4.5' wide across top. Two ramps on upstream side and downstream side of middle section 2' long, sloping down to pipe middle line.

2. Rating 1 verified to 6 cfs; rapid response times made higher gagings difficult. Plywood cutthroat flume installed to improve accuracy.

3. Rating 3 replaced Rating 2 to obtain high flow estimates; broadcrested weir approximations used as flume and flume wingwalls completely blocked lower end of pipe.

Station IP Description

Stream	Effluent from Blackbob Sewage Treatment Plant
Location - City	Olathe
County/State	Johnson County, Kansas
Street	Blackbob Rd. & Indian Creek Pkwy.
Description	Housing located at northwest corner of street intersection next to manhole 100' north of effluent discharge pipe into upper Indian Creek.
Basin Size	Not applicable; approximate plant discharge. 3.9 cfs low flow and 4.4 cfs during wet weather.
Flowmeter	Basin area upstream of discharge: 4535 acres. No flowmeter: plant flow records used and sampler set on ½ hour time composite basis
Raingage/Location	Tipping bucket gage installed on roof of housing, May 1982. Total volume gage (installed on roof) used when tipping bucket data not available.
Type of Channel Near Intake	18" RCP flows into box from west, 18" RCP with flap gate on end flows out of box south towards creek.

Notes:

1. A Manning Equation rating was developed for the incoming 18" RCP line using recorded depths and the recorded flows from the two plant flowmeters monitoring flow from two processes. The supercritical flow of the pipe and occasional surcharging due to high water levels in the stream prevented its rating from producing useable results. Plant flows were used in conjunction with time composite samples to calculate plant flows.

Station IR Description

Stream	Unnamed tributary of Indian Creek
Location - City	Overland Park
County/State	Johnson County, Kansas
Street	Near 92nd and Hayes
Description	Housing on south side of 92nd next to culvert about 90' east of Hayes.
Basin Size	63 acres
Flowmeter	0-3' ISCO 1870
Raingage Type/Location	None (vandalism problem)
Type of Channel Near Intake	Road culvert immediately upstream is 3' fall CMP arch pipe, further upstream is a concrete trapazoidal channel with 2.5' floor, 1-1/3 feet deep and 4.5' across the top.
Stage Discharge Relationship	Primary Device: Plywood Cutthroat Flume, 2' tall, 4.5' long, 15" throat. Flume attached to end of 8' approach box downstream of 3' arch pipe culvert.
June 1981 to April 1982	Rating 1
Peak Assured Accurate Flow	16.4 cfs
Highest Flow on Rating	64.4 cfs (sideweir approximation)
April 1982 to August 31, 1982	Rating 2
Peak Assured Accurate Flow	16.4 cfs
Highest Flow on Rating	19.7 cfs (sideweir approximation)

Notes:

1. 1982 Rating changed to produce lower full scale value on strip chart.

Station RC Description

Stream	Rock Creek Tributary
Location - City	Independence
County/State	Jackson County, Missouri
Street	1428 S. Noland Rd.
Description	Housing is in front of Burgraff Tire store next to manhole over street inlet box. 192' RCP from box flows almost immediately to Dobb's pond.
Basin Size	37 acres
Flowmeter	0-3' ISCO 1870
Raingage Type/Location	Total volume/set on stake near pipe outlet about 200' downstream (at back of tire store building).
Type of Channel Near Intake	27' downstream of 27" RCP opening is 30" RCP. Upstream of 27" RCP is 2.5' long x 10' wide junction box. Flowing into junction box are a 10' curb inlet and a 27" RCP.
Stage Discharge Relationship	Primary Device: 27" Palmer-Bowlus flume (Plasti-Fab Co. specifications)
Peak Assured Accurate Flow	15.8 cfs
Highest Flow on Rating	15.8 cfs

Station RR Description

Stream	Rock Creek Tributary
Location - City	Independence
County/State	Jackson County, Missouri
Street	Near 29th Terrace & Overton
Description	Housing at north (downstream) side of road shoulder on east side of culvert.
Basin Size	35 acres
Flowmeter	0-3' ISCO 1870
Raingage Type/Location	None
Type of Channel Near Intake	42" RCP under road; upstream is heavily eroded gully-drainage way.
Stage Discharge Relationship	Primary Device: 2½' sheet metal H-Flume attached to 6' cinder block approach box on end of 42" RCP culvert.
Peak Assured Accurate Flow	19.4 cfs
Highest Flow on Rating	19.4 cfs

Notes:

1. Flume installation destroyed during August 13, 1982 flood.

1.3.6 SAMPLING PROCEDURE

1.3.6.1 STORM EVENTS

NURP field crews often made rounds of the stations during storms to troubleshoot broken equipment and to collect in-situ data (D.O., temperature, and pH). The Johnson County field crews devoted considerable effort to these rounds and went out on almost all storms, including late night and cold weather events. A low sampling malfunction rate and a relatively complete record of wet weather in-situ data resulted from these site visits for the Indian Creek stations.

The Independence NURP team performed both laboratory and field work and had more difficulty in catching the shorter Rock Creek runoff events while the stream was high. Because of these limitations, less field information was collected on Rock Creek.

Microbial samples were collected at the stream stations if a field crew was on hand during a runoff event and if prompt laboratory analysis was possible. Grab samples, when collected, were taken by hand at the stream bank when the storm hydrograph was near peak flow. At stations with poor access, such as IS5 or during night sampling, a limited number of microbial samples were collected by taking a sample using the Sigmamotor sampler. Very few microbial samples were collected from Rock Creek.

Sampling continued until the flow fell below 10-25% of peak flow or to within 200% of any preceeding low flow discharge. Sample holding times varied considerably. Very few samples sat more than twelve hours in the housings after sampler shut down; most samples had holding times of four to six hours.

1.3.6.2 FIELD MEASUREMENTS

Dissolved oxygen and temperature data were collected using a YSI dissolved oxygen meter. The meter was calibrated using the Winkler Method before most sample runs; otherwise, calibration against the atmosphere was performed. pH data were collected using several portable pH meters calibrated against a pH 7 buffer. Difficulties with these small pH meters were encountered in both study areas and many storms lack any pH data at all.

Field data were usually measured at the stream bank; at sites with poor stream access (IS5) and during night sampling, samples for field probes were collected in buckets.

1.3.6.3 LOW FLOW SAMPLING

Low flow samples were collected by compositing three to four grab samples manually collected across the stream cross section. At IS5 samples were collected using a bucket lowered from the bridge. IP samples were collected off the Blackbob Road bridge instead of the outfall to obtain in-stream data. This low flow at Blackbob Road was very close to 100% effluent from the plant as little flow was observed from upstream of the discharge pipe. Low flow discharge values were estimated as the low flow ratings changed frequently from storm to storm. Analysis of all stream data and USGS flow records helped to strengthen flow estimates for the low flow sampling. Field data was collected during these low flow runs.

1.3.6.4 POST STORM SAMPLING

Several post storm samples were collected from one to three days after a storm event. Samples were collected in the same fashion as low flow samples if the water was low enough to allow wading. For higher flows, samples were collected using buckets lowered from nearby bridges.

1.3.6.5 TOXIC SCAN SAMPLING METHODS

The Kansas City area NURP project participated in a nationwide "toxic scan" survey, where several NURP studies were selected to collect EPA priority pollutant samples from urban runoff. The objective of the toxic scan was to identify the presence and the characteristics of any priority pollutants in urban runoff. For the Kansas City area NURP project, a total of 11 samples were collected during three storms at four land use stations (IC, II, RC, and RR).

The sampling procedure required five different sample types for each toxic scan collection:

Phenols
Cyanide
Volatile Organics
Extractible Organics
Heavy Metals

Each was collected according to EPA guidelines and immediately iced and preserved. Samples were taken to the EPA Region VII lab for analysis within twenty-four hours of collection.

One manually composited flow proportional sample was collected; all others were manually collected grab samples. Section 2.2.2.5 discusses the results of the toxic scan.

1.3.7 LABORATORY ANALYSIS METHODS

Test procedures were generally done according to the EPA's Methods for Chemical Analysis of Water and Wastes. Standard Methods of the Examination of Water and Wastewater (15th edition, 1980) was used as a supplementary reference.

1.3.7.1 HOLDING TIMES AND SAMPLE PRESERVATIVES

Samples were usually run well within the Standard Methods, 15th Edition, recommended maximum storage time and were almost always run within EPA's regulatory limits listed in proposed rules, Federal Register 44: No. 244, December 18, 1979.

No refrigeration or preservation techniques were employed at the sites due to the large manpower requirements needed to keep the sample containers iced. Samples collected in the Johnson County Study Area were iced during transport as a complete visit of all the sites took four to five hours. Samples collected in the Independence Study Area were not iced as less than an hour of driving time was required to make a full circuit.

Generally, samples were split, filtered, and refrigerated immediately at both laboratories. Some late night samples were stored in the refrigerator until the next morning when they were split, filtered, and refrigerated.

No chemical preservatives were employed if all analyses were to be run immediately by the laboratories. For analyses requiring more than an eight hour holding time in the lab, appropriate chemical preservatives were added. Most analyses requiring 48 hour holding times were run within one day after the field crew's last station visit when the samples were picked up.

Exceptions to holding time recommendations were most frequent with heavy metals samples and BOD samples. Few BOD samples were run within the six hour holding time; most were prepared for the five day analysis within twelve hours, and none were run if more than a twenty-four hour holding time was reached. Because of delays in installation of an atomic absorption unit, heavy metals analyses were not started until July 1982. Most metal samples collected in 1981 (except several samples taken to a private testing lab) exceeded the recommended six month holding time.

Samples in the two and a half gallon containers were split into similar volumes using a USGS designed cone splitter. The cone splitter produced ten sample streams which could be used to create subsamples for various test series.

Samples were usually prefiltered with Whatman paper filters before using a Gelman filtering apparatus with .45 micron pore filters. Several filters had to be used for most samples because of the tremendous turbidity found in the runoff samples.

Sample Holding Time Summary

Parameter	Abbreviation	Usual Longest Holding Period[1] 24 hrs.	Usual Longest Holding Period[1] 7 day	Holding Time Recommended[2]/Regulatory[3]	Chemical Preservative
Total Suspended Solids	TSS		X	7 days/7-14 days	---
Total Phosphorus (Total)	TPT	X		48 hrs/48 hrs	H_2SO_4, ph < 2
Total Kjeldahl Nitrogen (Total)	TKNT	X		7 days/28 days	H_2SO_4, ph < 2
Chemical Oxygen Demand	COD		X	7 days/28 days	H_2SO_4, pH < 2
Biological Oxygen Demand	BOD	X		6 hrs/48 hrs	---
Chloride	CL^-		X	7 days[2]	---
Heavy Metals (Total)[4]	Pb,Cd,Cu,Zn Mn,Fe,Na			6 mon/6 mon	HNO_3, pH < 2
Total Phosphorus (Soluble)	TPS	X		48 hrs/48 hrs	H_2SO_4, pH < 2
Orthophosphate	PO_4	X		48 hrs/48 hrs	---
Total Kjeldahl Nitrogen (Soluble)	TKNS	X		7 days/28 days	H_2SO_4, pH < 2
Ammonia	NH_3	X		7 days/28 days	H_2SO_4, pH < 2
Nitrate + Nitrite	NO_3+NO_2	X		---/28 days	
Nitrite	NO_2	X		---/28 days	---
Heavy Metals (Soluble)[4]	Pb,Cd,Cu,Zn Mn,Fe,Na			6 mon/6 mon	HNO_3, pH < 2
Specific Conductance	SCOND		X	28 days/28 days	---

[1] Period between last station visit and analysis.

[2] Standard Methods 15th Edition.

[3] From EPA Methods for the Chemical Analysis of Water and Wastewater (March 1979).

[4] Metals samples were immediately preserved, stored, and then run during July-October, 1982. Most samples collected before February, 1982 exceeded the six month holding time.

1.3.7.2 ANALYSIS METHODS

Parameter	Method	Reported Units
Total Suspended Solids	Glass Fiber filtration, 105°C	mg/l
Total Phosphorus	Persulfate digestion followed by manual ascorbic acid reduction	mg/l as P
Orthophosphate	.45 micron filtration, manual ascorbic acid reduction	mg/l as P
Total Kjeldahl Nitrogen	Digestion and distillation followed by titration (Johnson County Unified Wastewater Districts) Electrode (Independence)	mg/l as N
Ammonia	.45 micron filtration, distillation followed by titration (JCUWD) Electrode (Independence)	mg/l as N
Nitrate	.45 micron filtration, cadmium reduction followed by colormetric diazotization minus nitrite	mg/l as N
Nitrite	.45 micron filtration, colormetric diazotization	mg/l a N
Chemical Oxygen Demand	Dichromate Reflux	mg/l
Biological Oxygen Demand (5-day)	Winkler titration	mg/l
Chloride	Electrode (Independence) Silver Nitrate titration (JCUWD)	mg/l
Specific Conductance	Wheatstone Bridge conductimetry	micromhs per c at 25°C
Fecal Strepticocci, MF	M-enterococcus agar, 35°C, 48 hr.	colonies/100 ml
Fecal Coliform	EC-media 44.5°C	MPN/100 ml

Dissolved Oxygen	Field Electrode measurement	mg/l
pH	Field Electrometric measurement	pH units
Lead (Total)	Digestion followed by atomic absorption	µg/l
Cadmium (Total)	Digestion followed by atomic absorption	µg/l
Copper (Total)	Digestion followed by atomic absorption	µg/l
Zinc (Total)	Digestion followed by atomic absorption	µg/l
Manganese (Total)	Digestion followed by atomic absorption	µg/l
Iron (Total)	Digestion followed by atomic absorption	µg/l
Lead (Filtered)	.45 micron filtration atomic absorption	µg/l
Cadmium (Filtered)	.45 micron filtration atomic absorption	µg/l
Copper (Filtered)	.45 micron filtration atomic absorption	µg/l
Zinc (Filtered)	.45 micron filtration atomic absorption	µg/l
Manganese (Filtered)	.45 micron filtration atomic absorption	µg/l
Iron (Filtered)	.45 micron filtration atomic absorption	µg/l
Sodium	Digestion followed by atomic absorption	µg/l

1.3.7.3 LABORATORY QUALITY ASSURANCE

A three element program was used to assure lab quality controls: precision control charts, accuracy control charts, and analysis of synthetic samples. Precision was measured for each analysis by analyzing at least one duplicated sample per run. Accuracy data were developed for all tests that allowed for the addition of laboratory spikes (TP, NO_3, NO_2, NH_3, and Cl^-). This was done for at least every other run. Both the duplicate and spike data were compared against control charts established before the start of most sampling to determine whether the errors of an analysis are random or systematic in nature, and to determine their relative magnitude. An analysis within the limits expected of random was considered "in control". An analysis "out of control" was evaluated to determine any systematic or major problems.

The control chart theory developed by Walter Shewart and discussed in EPA's Handbook for Analytical Quality Control in Water and Wastewater Laboratories was used for the Kansas City Area NURP program.

For precision control charts, at least fifteen duplicate samples were used to obtain a mean range. The Upper Control Limit on the range (UCL_r) was then calculated using: $UCL_r = D_4R$ (R = range between duplicates). For duplicate samples, D_4 is 3.27 when three standard deviations are used to fix the UCL_r.

The high variability in sample concentrations caused high UCL_r for some analyses, particularly TSS. The TSS duplicate data were expressed as relative ranges (% difference divided by mean of duplicates), and the UCL_r was expressed in the same fashion as a percentage.

Accuracy control charts were constructed by calculating a mean percent recovery from at least fifteen spiked samples. The percent recovery calculation was:

$$P = \frac{100\ (O-B)}{T}$$

P = Percent recovery
B = Background concentration in sample
O = Observed value after spiking
T = Actual value of spike

An Upper Control Limit (UCL) and Lower Control Limit (LCL) were calculated from a three standard deviation range around the mean percent recovery:

$$UCL = P + 3 \cdot SD$$
$$LCL = P - 3 \cdot SD$$

Accuracy and precision control chart limits for each laboratory's analysis are shown in the following table.

Accuracy and Precision Control Chart Data

A· Accuracy (percentage spike recovery) control range
P: Precision (difference of duplicate samples) control range

		JCUWD	Independence
TSS	A	---	---
	P	18%	29%
TP	A	80-120%	83-116%
	P	±.11 mg/l	±.02 mg/l
PO_4	A	---	78-118%
	P	±.03	±.03
TKN	A	---	---
	P	±.59	±2.7
NH_3	A	61-129%	58-138%
	P	±.18	±.13
NO_3	A	80-120%	92-130%
	P	±.06	±.03
NO_2	A	82-107%	77-100.1%
	P	±.006	±.003
BOD	A	---	---
	P	±13	±10
COD	A	---	---
	P	±24	±19
CL^-	A	---	---
	P	±3	±31

Two types of synthetic samples were analyzed regularly during the program. As a contamination check, one blank sample (deionized water) was analyzed during each run for all parameters. EPA quality assurance samples were run roughly every two months, and laboratory results were compared against the EPA measured value. These samples served as a final check on laboratory quality assurance limits.

The general accuracy limits of each test were derived from the precision and accuracy control charts for each lab.

1.3.7.4 SPECIAL ANALYSIS PROCEDURES

Dryfall samples were analyzed by removing any large non-dustfall related particles such as leaves or bird droppings. A premeasured amount of deionized water (usually two liters) was then added to the sample container, and the accumulated material was mixed into solution. A spatula was sometimes used to scrape the accumulated material off the sides.

A few low volume precipitation samples (< 500 ml) were diluted to increase sample volume. Most of the time analysis requiring large amounts of sample (usually BOD and NH_3) were not run when sample volumes were limited.

1.3.8 HEAVY METALS ANALYSIS

Interpretation of the heavy metals data was complicated because four different atomic absorption (AA) spectrophotometers with significantly different lower detection limits were used. All but a few of the heavy metals data were obtained by using one of two JCUWD AA units. The "old AA" was purchased in 1972 and had significantly higher detection limits than the "new AA," which was operational in June 1982. In addition, one sample event was analyzed using a private testing lab (General Testing Lab or GTL) and one event was sampled for the Nationwide NURP Special Metals Survey, where VESAR labs analyzed for 29 heavy metals. The sampling dates and respective heavy metals method are listed below.

JCUWD "new AA"	All storms after 4/28/82 and Rock Creek storms sampled on 10/5/81, 10/13/81, 11/1/81/, 11/4/81, and 11/8/81.
GTL Labs	Indian Creek samples from the 8/6/81 storm
JCUWD "old AA"	All other samples analyzed for heavy metals
NURP Special Metals Survey	Storm of 5/5/82

The lower detection limits for the "new" and "old" JCUWD AA units and the GTL unit are listed below.

HEAVY METALS LOWER DETECTION LIMITS (μg/l)

Parameter	"Old AA"	"New AA"	GTL[1]
Na	100	1	10
Zn	10	8	10
Pb	100	100	1
Fe	360	40	10
Cu	500	30	1
Cd	500	10	1
Mn	100	20	1

[1] One storm event only

The sensitivity of even the "new AA" unit was often insufficient to detect the extremely low metals concentrations in many samples. The number of samples below detection limits is listed in Section 2.0. Special handling of the metals concentration data reported at lower detection limits was required, as explained in Section 1.4.3.1.

1.4 DATA ANALYSIS METHODS

1.4.1 LAND USE DATA REDUCTION TECHNIQUES

Land use information was usually compiled following the NURP Data Management Procedures Manual guidelines. Sources of this information follows. All areas taken from maps were measured using a Neumonics electronic planimeter.

1. **% Urban Land Uses** - Planning Land Use maps from area municipalities were acquired and areas were measured. The City maps used were:

   Independence, Mo.
   Overland Park, Ks.
   Lenexa, Ks.
   Leawood, Ks.
   Merriam, Ks.
   Olathe, Ks.
   Johnson County, Ks. (for unincorporated areas)

2. **% Agriculture** - Soil Conservation Service data for Johnson County agricultural areas were used. No significant agricultural areas were found in the Rock Creek Watershed.

3. **Areas Under Construction** - Representatives of City Planning Department mapped construction areas which were then measured. Field checks were performed in November 1981 to verify construction in those areas.

4. **Total Area** - USGS Quadrangle maps were used to outline watersheds for RS1, RS2, RS3, IS1, IS2, IS3, IS4, and IS5. Small scale city topographic maps (from 1"=100' to 1"=200') were used for RC, RR, II, IR, and IC.

5. **% Impervious** - Land use descriptions from the SCS TR-55 were used to estimate percentage impervious for different land uses. The values used were:

	% Impervious
Commercial	85%
Industrial	72%
High Density - Residential, Schools	65%
Medium Density - Residential	38%
Low Density - Residential	25%
Park, Public	15%
Open, Vacant	10%

Basins with composite land uses were calculated using these values distributed according to land use designation. Land use sites data were obtained from 1"-100' planning maps.

6. **Slope of Drainage Basin** - Average from ridgelines to main stream channels were calculated for at least twenty slope lines using USGS Quadrangle maps for all stations except IC, II, IR, RC and RR. Planning maps (1"=100' or 1"=200') were used for these stations.

7. **Slope of Drainage Channel** - The Data Management Procedures Manual method of calculating the channel slope between 10% and 85% of the way up the drainage channel was used.

8. **Portion of Area with Storm Sewers** - This information was collected from the best data available to local City Engineers.

9. **Portion of Streets with Curb and Gutters** (same as 8).

10. **Portion of Streets with Swales and Ditches** (same as 8).

11. **% Soil Group B** - SCS soil maps were used to obtain these data.

12. **% Soil Group C** (same as 11).

13. **% Soil Group D** (same as 11).

14. **Available Water Capacity** - The SCS supplied these data from the soil description.

15. **Soil Permeability** (same as 14).

1.4.2 HYDROLOGIC PARAMETER REDUCTION

Data for eight hydrologic parameters were collected for each storm at each station. Flow data were unique for each site, and most stations had unique total rainfall data. Storm intensity, duration, and antecedent rainfall data were often the same for many stations because at the most two, and sometimes only one, recording raingage was in operation for each event.

Parameter	Abbreviation	Units	Definition
Peak Flowrate	(Q_p)	cfs	The highest flow recorded during a storm.
Base Flowrate	(Q_b)	cfs	The flow prior to the first definite rise due to a storm.
Total Discharge Volume	(V_{tot})	ft^3	The area under the hydrograph from the first definite rise to a point representing about 150% of the baseflow value, or if no baseflow, to a zero flow.
Duration	(Dur)	hrs	The duration of an event from the first definite rise to the defined end of an event (see V_{tot} definition).
Runoff Volume	(V_{ro})	ft^3	The result of subtracting base flow from total discharge volume using: Vro = Vtot - (Qb · DUR · 3600)
Total Volume Precipitation	(P)	inches	The average rainfall over a basin. For the stream site basins, rainfall from all functioning gages was distributed over the basin using the Thiessen method. For the land use sites individual total volume raingage values were used. For land use stations without a raingage, the closest one was used: RR used Fire Station #5, IR used the IS4 gage.

Rainfall Intensities	$(I_5, I_{15}, I_{60}, I_{ave})$	in/ hour	The maximum rainfall occurring over a five minute, 15 min., 60 min. period, and average for the entire rainfall; duration was defined as the period between the start of th first .01" of rain after a six hour dry period and the end of the last .01" before a six hour dry period.
Antecedent Dry Period	(ADP)	days	The period between storms wit total rainfall greater than .02"

1.4.3 LOADING CALCULATIONS - GENERAL

1.4.3.1 INDIVIDUAL STORM LOADS

Storm loads were calculated for individual events at each site when the required input data were available. The calculation involved multiplying the parametric event mean concentration (mg/l) by the total volume of flow (cubic feet) and then multiplying this product by an appropriate conversion factor to give the storm load in pounds. This loading calculation was performed on an event-by-event basis for each parameter at every station when both the parametric and hydrologic data were available. Total nitrogen loads were calculated as the sum of the total Kjeldahl nitrogen, nitrate, and nitrite loads. Normalized loads were determined by dividing the individual storm loads by the corresponding catchment area acreage.

1.4.3.2 ANNUAL LOADS

The individual storm loads served as the basis for the annual load calculations. For each station, the individual storm loads were summed to produce the "total measured load". This value was then extrapolated to an annual load for each station by one of two methods. A simple precipitation based method was used for all sites with the exception of the major stream stations. For these major stream stations (IS1, IS3, IS5, RS1, RS2 and RS3) a runoff volume extrapolation procedure was used. Annual metals loading rates were expressed as a range when one or more samples were reported as below detection limits. The lower end of the range was calculated by assigning a zero load to samples with concentrations reported as less than detection limits and entering these loads in the annual loading calculation. The upper end of the range was determined by assigning concentrations equal to the reported detection limit of the instrument to these cases and entering the resulting loads in the annual loading calculation. In general, an increased number of cases reported as below detection limits, resulted in a greater range in the annual loading rate reported. Higher lower detection limits also increased the reported annual loading range for metals.

Precipitation Based Method

For IS2, IS4, and the land use sites, the extrapolation from total measured load to annual load was done on the basis of "total measured precipitation". The procedure involved computing the total measured precipitation as the cumulative sum of the precipitation values (in inches) for only those events with storm loads calculated for the particular parameter. The portion of a year actually measured was then estimated for each site as the ratio of the expected annual precipitation (39.93 inches in Kansas City) to the total measured precipitation. The total measured load was then multiplied by this ratio to yield the estimated total annual load. Normalized annual loads were determined by dividing the estimated annual load by the catchment area acreage.

Runoff Volume Based Method

For the major stream sites, a runoff volume extrapolation procedure was used to calculate annual loads. Annual runoff volumes were estimated for IS3 and RS1 by a base flow separation technique applied to available USGS historic flow records. The annual runoff volumes determined for IS3 and RS1 were then used to estimate IS1 and IS5 annual runoff volumes and RS2 and RS3 annual runoff volumes, respectively.

Annual runoff volumes for Indian Creek major stream stations were determined by applying information from SYNOP (Synoptic Rainfall Analysis Program)[1] to USGS flow data at IS3 from 1963 to 1980. According to SYNOP, a software package developed for EPA by Hydroscience Associates, Inc., and used to evaluate Kansas City area rainfall records for the years 1950 through 1976, the number of events per year in the Kansas City area averages 108.5. If it is assumed that each event increases stream stage for an average period of 12 hours, then stream stage is increased due to runoff 54.3 days per year or approximately 15 percent of the time. This figure was used to apportion USGS records into runoff days and base flow days. USGS records from water years 1975, 1978, and 1979 were selected for analysis because mean daily flows for these years were comparable to the mean daily flow for the entire 17 years of USGS record. For these three years, approximately 15 percent of the mean daily discharges are greater than 22 cfs. This value was used as the critical mean daily discharge. Days with mean daily discharges less than 22 cfs were classified as base flow days. Days with mean discharges of 22 cfs or more were classified as runoff days. A sharp jump in the cumulative frequency plot of daily mean flows for IS3 at approximately 22 cfs supports the use of this value. For each of the water years, 1975, 1978, and 1979, the total flow volume on base flow days was determined. This "base flow volume" was then divided by the number of base flow days to give a mean daily base flow value for each of the three years. These mean daily base flow values were then averaged for the three years to produce the final average daily base flowrate. This value was then subtracted from the average daily flowrate from 17 years of records at IS3 to determine the average daily runoff flowrate which was then converted to an annual runoff volume.

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[1] Hydroscience Associates, Inc., "Synoptic Rainfall Data Analysis Program (SYNOP)", EPA Contract No. 68-01-2428, Report Nos. EPA-600/9-76-014 and EPA/DF-N-002 (NTIS PB 264566 and PB 264563), July 1976.

Annual runoff volumes at IS1 and IS5 were estimated by comparison to the IS3 annual runoff volume. This was done at IS1, for example, by multiplying the annual runoff volume at IS3 by the average ratio of individual storm runoff volumes between IS1 and IS3 for those events which had flow data for both stations. Likewise, IS5 annual runoff volume was estimated by multiplying the annual runoff volume at IS3 by the average ratio of individual storm runoff volumes at IS5 and IS3 for corresponding events.

The same overall procedure was used to estimate annual runoff volumes for Rock Creek. From seven years of USGS record at RS1, a value of 5 cfs was determined as a criterion to separate baseflow days and runoff days. Mean daily base flow was then determined to be approximately 1 cfs, and this value was subtracted from the mean daily discharge rate from seven years of record and converted to an annual basis to yield annual runoff volume for RS1. Annual runoff volumes for RS2 and RS3 were estimated relative to RS1 by the same procedure used for the Indian Creek sites.

Once annual runoff volumes had been established, calculating annual loads proceeded in much the same manner as the precipitation method. Individual storm loads were summed for each station to produce the total measured loads. The storm runoff volumes associated with each load were summed to give the "total measured runoff volume". Estimated annual parametric loads were then computed for each station as the product of the total measured load and the ratio of annual runoff volume to total measured runoff volume. Normalized loads were again determined by dividing annual load by catchment area acreage.

An additional procedure was required for the Indian Creek major stream sites (IS1, IS3, IS5) to eliminate the contribution made by the Blackbob Wastewater treatment facility to more accurately determine the net contribution of nonpoint sources. For each event, point source parameter concentrations and flowrates were combined to produce a loading flux in pounds per hour for each parameter. These loading fluxes were then multiplied by the duration of the particular event at each of the three sites to determine the point source contribution to the load at that site. These point source loads were then subtracted from the total calculated loads at each site to leave actual nonpoint source loads. These reduced loads were then entered into the annual loading calculation previously described to determine the normalized annual loadings for the three sites independent of the point source.

1.4.3.3 MISSING VALUES

Parameter event mean concentration (EMC) and total flow volume were necessary inputs to the individual storm load calculation. If one or both of these values were missing, the parameter storm load could not be calculated for the event.

For estimating the annual parameter load by the precipitation based method, parameter storm loads and precipitation values were required inputs for each event. If one or both of these values were missing, the particular event did not enter into the annual load calculation. Likewise, for estimating annual parameter loads on a runoff volume basis, both the parameter storm load and the associated storm runoff volume were required for the particular event to enter into the calculations.

1.4.4 COMPUTERIZED DATA MANAGEMENT SYSTEM

Three computer systems were involved in the project data management system. The Statistical Program for the Social Sciences (SPSS) was installed into the Johnson County Data Services IBM mainframe computer in April 1982. It was used for storing, manipulating, and performing most calculations on the NURP data. In addition, it was used to generate punched data cards for the EPA's nationwide computer data base, STORET.

First, data were keypunched from handwritten data logs and lab sheets for entry onto member files on the IBM operating system. SPSS code was written around these member files to create SPSS system files that could be stored, altered, merged, or purged. All the SPSS data were hand checked for coding errors. Next, SPSS code was written to transform the data to a facsimile STORET "04" free field format and then write these cases as output. PL-1 programs then acted on the output to remove imbedded blanks in order to transform it to exact STORET "04" format. These data were then punched on cards that were mailed to EPA headquarters in Washington, D.C.

Data analysis began in earnest once the STORET cards had been prepared and mailed. Statistics and data summaries were produced, and working data plots were developed. Data tables and summaries were printed with the SPSS report generator.

Some subsets of the data were entered into an HP-87 microcomputer system for data analysis and for data plotting. Low flow data, land use station loading data, and benthic data were stored and summarized using VISICALC electronic worksheet software and VISILINE, VISIBAR, and VISICURVE graphics software. Selected plots for the final report were also entered into the micro for production of high quality graphics.

1.4.5 BENTHIC DATA ANALYSIS

Benthic macroinvertebrate data were collected eight times at ten sites by two sampling methods: Quantitative sampling using a Surber Square Foot Sampler and qualitative sampling where an entire riffle was inventoried over a ten minute time period. Sites were selected to cover the part of the Indian Creek basin sampled in the NURP program with half of the sites above IS1 and half below IS1. The intent of this design was that the sites above IS1 reflect the impact of the Blackbob Wastewater Treatment Plant; those below IS1 reflect the impact of nonpoint source runoff. Data collection spanned 3½ years from the Fall of 1978 through the Spring of 1982.

Data collected quantitatively are not directly comparable with data collected qualitatively, so a data standardization methodology was developed to generate a uniform data base reflecting the relative abundance of each organism in each sample collection and an assessment of biomass at each site. This procedure involved the development of 16 classes with a total range of from 0-900 organisms. Each class contained a designated range of number of organisms (i.e. class 1 contained 0-3 organisms and class 15 contained 700-900 organisms). The mean of the range of each class was expressed as a percentage of 900; this number was termed the "class value".

Identified organisms were assigned to the class best representing their abundance as seen during qualitative field sampling. Replicate analyses were made at each site, and the class values for each organism were averaged resulting in the assignment of one standardized number to each organism at each site during each collection. This standardized number reflects the relative abundance of each organism and gives an assessment of total biomass at each site.

Quantitative samples were counted and identified in the laboratory according to the method described in Biological Field and Laboratory Methods, EPA-670/4-73-001, Macroinvertebrate Chapter. Each organism was given a class value according to total numbers counted, and replicate samples were averaged as in the qualitative samples.

These standardized data were tabled by site and organism for each of the eight collections. Data analyses were performed on three different groupings of these data:

1. By individual collection
2. By site with collection pooled (spatial analysis)
3. By collection with sites pooled (temporal analysis)

These groupings allowed several levels of analyses to be made:

1. Changes in the entire community through time, reflecting increased urbanization.
2. Changes in the community from upstream to downstream, reflecting the zone of impact of the effluent discharge, recovery, and changes occurring in the urbanized stream reach.

3. Changes in the community from upstream to downstream with seasonal data pooled.

Data were evaluated by single number summaries and by organism sensitivity analyses. Parameters for single number summaries were:

1. Number of Collections
2.* Standardized Total Organisms
3. Mean Number of Organisms
4. Total Different Taxa
5. Range of Taxa
6. Mean Number of Taxa
7. Range of Species Diversity (d)
8. Mean d

Two types of organism sensitivity analyses were performed: Tolerance to organic pollution and indicator community percentage. In the tolerance to organic pollution analyses, each organism was assigned a classification of tolerant, faculative, and intolerant based on literature reports as follows:

> **Tolerant** - Organisms frequently associated with gross organic contamination and generally capable of thriving under anaerobic conditions.
>
> **Faculative** - Organisms having a wide range of tolerance and frequently associated with moderate levels of organic contaminants.
>
> **Intolerant** - Organisms that are not found associated with even moderate levels of organic contaminants and generally intolerant of even moderate reductions in dissolved oxygen.

For the indicator community percentage analysis, organisms were assigned to major groups with one group being the endemic mayfly, caddisfly, stonefly, riffle beetle association that is characteristic of relatively unpolluted streams in Johnson County. Changes in the percentage contribution of this group to the total community were followed for the three different groupings described above.

More detailed methodology descriptions and results of these analyses are given in Chapter 6.

2.0 POLLUTANT CONCENTRATION ANALYSIS

Pollutant concentrations of urban runoff are often compared against water quality standards. The intermittent and highly variable nature of urban runoff, however, creates difficulty in assessing its water quality impact. The frequency of occurrence of a water quality constituent will affect the level of impairment of beneficial use as much as will the actual magnitude of the concentration. This requires that a comparison of urban runoff quality data against criteria incorporate the frequency at which various pollutant concentrations are equalled or exceeded.

In this section, basic statistical functions are used to characterize the NURP concentration data. The distribution of various pollutants in various states and chemical species are described. Finally, the NURP data are compared to water quality criteria and standards.

Dry weather, wet weather, and post storm event pollutant concentration data are included in this analysis. The NURP monitoring stations are divided into three groups: Land use stations, Rock Creek stream stations, and Indian Creek stream stations.

2.1 DRY WEATHER

2.1.1 ROCK CREEK DRY WEATHER CONCENTRATIONS

Low flow sampling runs were performed on the Rock Creek stream stations (RS1, RS2, and RS3) on these dates:

	Date	Run Number
1.	7/21/81	601
2.	9/23/81	611
3.	2/17/82	607
4.	3/31/82	609
5.	4/21/82	610
6.	7/29/82	612

The entire chemical analysis series was performed on these samples.

2.1.1.1 CONCENTRATION SUMMARY

Low flow concentrations in Rock Creek were generally much lower than found during wet weather or during dry weather in Indian Creek. Little variation in concentrations between the three stations was observed. Comparison between different low flow sampling runs showed larger differences, however. Most of the parameter concentrations seemed to move up or down together for different runs, indicating different degrees of dilution for different runs. Low flow concentration data are summarized for a representative station (RS3) in Table 2.1.

Section 2.2.1.1 and Section 1.3.8 discuss the heavy metals analysis procedure. Only zinc, iron, manganese, and sodium were found above detectable limits in low flow samples. Several zinc samples were found below the 10 µg/l detection limit; the uncertainty of these data affected the means (which were calculated assuming a 10 µg/l concentration) by less than 5%. The mean zinc concentration was extremely high at all three stations, suggesting an industrial discharge upstream of RS1.

All lead, cadmium and copper samples were measured at lower than the detection limit: 100, 10, and 30 µg/l respectively.

Table 2.1
Rock Creek Low Flow Concentrations (Station RS3)
(mg/l unless reported otherwise)

	Mean	Range
TSS	15	4-24
TPT[1]	.19	.11-.35
PO_4[1]	.07	.02-.17
TOTN[2,3]	1.7	1.2-2.0
TKN[2]	.79	.52-1.0
NH_3[2]	.15	.05-.23
NO_3[2]	.76	.52-.98
NO_2[2]	.015	.004-.024
COD	18	13-23
BOD	2.7	2.3-3.5
Na	41	24-61
Zn[4]	1,060	< 8-2,360
Fe[4]	700	390-1078
Mn[4]	450	289-748
Cu[4]	< 30	< 30
Pb[4]	< 100	< 100
Cd[4]	< 10	< 10

[1] as P
[2] as N
[3] calculated value
[4] µg/l

2.1.1.2 SOLUBLE/INSOLUBLE FRACTIONS

The majority of both phosphorus and nitrogen found during low flow was in the soluble phase. Generally only 20-50% of the phosphorus was attached to sediment being transported down the stream. The total Kjeldahl nitrogen insoluble percentage was even smaller and was usually below 30%.

RS3 Low Flow Concentrations
Mean Insoluble Fraction (%)

TKN	TP
19	41

The metals soluble fraction varied greatly from sample to sample. Zinc and manganese were generally found in the soluble phase (less than 25% of the samples were less than 50% soluble zinc and manganese) and iron was mostly insoluble (73% of the samples were less than 50% soluble iron).

2.1.1.3 CHEMICAL DISTRIBUTION

Most of the low flow nitrogen was in the organic nitrogen and nitrate forms. Ammonia nitrogen never made up more than 20% of total nitrogen. The nitrite form was even less significant, never accounting for more than 1.5% of the total nitrogen.

A weak pattern showing oxidation of the ammonia form to the nitrate form was observed. The average nitrogen fraction as ammonia dropped from RS1 to RS3, however, and nitrate fractions increased.

Mean Fraction of Total Nitrogen (%)

	RS1	RS2	RS3
Ammonia	13	12	9
Nitrate	37	37	44

Orthophosphate fractions of total phosphorus ranged from 7% to 64%. Much of the variation was due to the low phosphorus concentrations, which were often close to the laboratory's sensitivity limit.

2.1.2 INDIAN CREEK DRY WEATHER CONCENTRATION

2.1.2.1 CONCENTRATION SUMMARY

Nine NURP low flow runs were performed in Indian Creek on these dates·

Run Number	Date	Stream Stations Sampled	Chemical Analysis Performed
602	9/22/81	all	all
603	10/27/81	all	all
604	12/09/81	all	all
605	1/26/82	all	all
606	2/03/82	all	all
608	3/10/82	all	all (but TKNS)
610	4/21/82	all	all
613	8/04/82	IP,IS1,IS3,IS5	TSS,TPT,NH_3,COD
614	9/16/82	IP,IS1,IS3,IS5	TSS,TPT,NH_3,COD

Most of the data analysis summaries include only the first seven runs; the partial data from the last two runs were used to confirm trends.

The four stream stations representing the main channel of Indian Creek (IP, IS1, IS3, and IS5) were dominated by the effluent from Olathe's municipal treatment plant. Station IP was sampled in the stream for dry weather runs and represented a stream station. The two tributary stream stations (IS2 and IS4) were much more like Rock Creek, which has no treatment plant discharge.

Mean concentrations and ranges for the upstream and downstream stations (IP and IS5) and for one tributary station (IS4) are shown in Tables 2.2 and 2.3 to summarize the low flow data base. The complete set of the data are shown in the appendix.

Only zinc, sodium, iron, and manganese were found above detection limits during low flow. Indian Creek dry weather zinc concentrations were five to ten times smaller than the Rock Creek concentrations; the other metal parameters were comparable. Lead, copper and cadmium were always found below detection limits.

Dilution of the treatment plant effluent by springs and dry weather base flow was seen at the downstream main channel stations. Figure 2.1 shows the average concentration of TSS, TP total, TP soluble, and Total Nitrogen for Indian Creek at IP and the three downstream stations. This dilution was seen for both soluble and insoluble parameters.

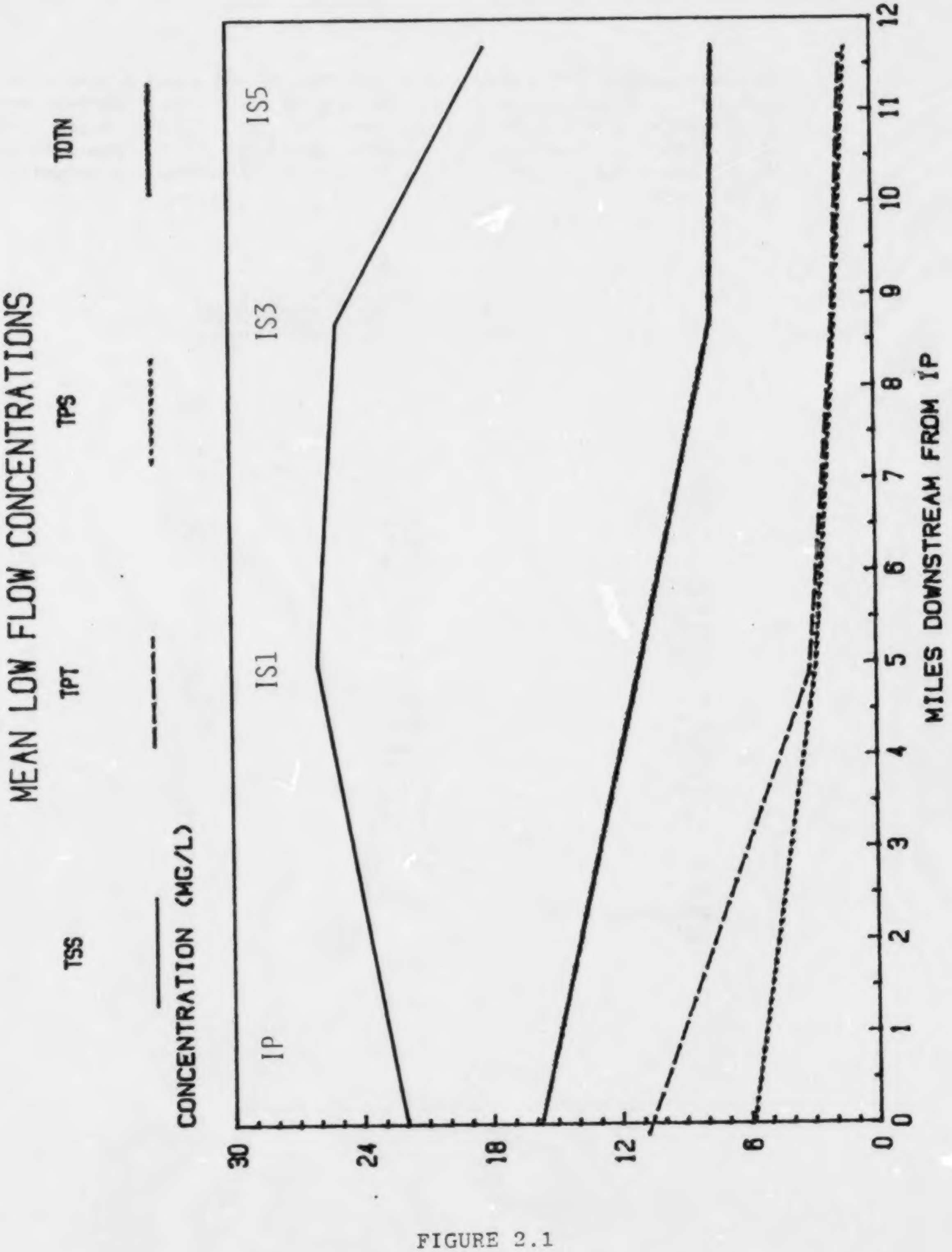
MEAN LOW FLOW CONCENTRATIONS
TSS
TPT
TPS
TOTN
CONCENTRATION (MG/L)
IP
IS1
IS3
IS5
30
24
18
12
6
0
0
1
2
3
4
5
6
7
8
9
10
11
12
MILES DOWNSTREAM FROM IP

FIGURE 2.1

Dissolved oxygen (DO) values varied with season and water temperature. Two violations of Kansas water quality standards (5 mg/l) were recorded; both were at station IS3 and occurred in September, 1981 (run 602) and August, 1982 (run 613). Table 2.4 summarizes the DO data. Only three DO readings were taken at the treatment plant outfall (Station IP); the DO concentrations ranged from 7.4 to 10.4 mg/l.

Table 2.2
Indian Creek
Mean Low Flow Concentrations
(mg/l unless reported otherwise)

	IP	IS5	IS4
TSS	22	18	14
TP^1	9.8	1.4	.16
$PO_4{}^1$	5.3	1.2	.04
$TOTN^{2,3}$	15.8	7.4	2.7
TKN^2	14.6	3.9	.97
$NH_3{}^2$	10.2	1.7	.32
$NO_3{}^{2,3}$	1.1	3.3	1.7
$NO_2{}^2$	.14	.21	.02
COD	99	30	26
BOD	26	6	4.2
Na	80	58	63
Zn^4	236	273	111
Fe^4	401	815	690
Mn^4	143	257	142
Cu^4	< 30	< 30	< 30
Pb^4	< 100	< 100	< 100
Cd^4	< 10	< 10	< 10

1 as P
2 as N
3 calculated value
4 µg/l

Table 2.3
Indian Creek
Low Flow Concentration Ranges
(mg/l unless reported otherwise)

	IP	IS5	IS4
TSS	9-47	1-58	4-29
TP^1	7.4-14.6	.75-1.70	.02-.26
PO_4^1	3.2-8.3	.43-1.60	.01-.07
TOTN^{2,3}	10.6-22.9	5.2-13.4	1.3-6.2
TKN^2	9.0-22.0	1.6-7.0	.4-1.6
NH_3^2	4.6-17.0	.1-4.4	.1-.6
$NO_3^{2,3}$	.03-2.0	1.6-6.3	.17-5.8
NO_2^2	.02-.27	.06-.83	.00-.04
COD			
BOD	12-38	3.7-10.6	2.2-7.6
Na	58-117	35-79	35-95
Zn^4	< 10-680	< 10-760	< 10-420
Fe^4	< 360-470	470-1770	339-1370
Mn^4	< 100-150	< 100-780	< 100-198
Cu^4	< 30	< 30	< 30
Pb^4	< 100	< 100	< 100
Cd^4	< 10	< 10	< 10

1 as P
2 as N
3 calculated value
4 µg/l

Table 2.4
Low Flow Dissolved Oxygen Concentrations - Indian Creek

	Ranges (mg/l)	Mean of Main Channel Stations IS1, IS3, IS5 (mg/l)	Mean of Tributary Stations IS2, IS4 (mg/l)
Summer	4.1-7.7	6.0	7.5
Fall	7.6-13.2	10.0	10.3
Winter	9.9-14.2	12.4	13.1
Spring	8.4-9.6	9.2	9.6

2.1.2.2 SOLUBLE/INSOLUBLE FRACTIONS

Phosphorus and Total Kjeldahl Nitrogen exhibited different soluble/insoluble distributions. The municipal treatment plant effluent showed a wide range of soluble phosphorus fractions between 37% to 93%. The three downstream stations (IS1, IS3, and IS5) had more phosphorus in the soluble phase: All low flow samples had more than 80% soluble phosphorus. The loading summary (Section 3.3.2) discusses a settling out trend for phosphorus. The distribution of total Kjeldahl nitrogen showed more variability and soluble fractions ranged from 20% to 100%. The average soluble fractions for each station were all between 44% soluble (Station IS5) to 69% soluble (Station IS3) Kjeldahl nitrogen.

Low Flow Data Mean Soluble Fractions (%)
Indian Creek

	Phosphorous	Total Kjeldahl Nitrogen
IP	59	62
IS1	91	54
IS3	93	69
IS5	90	44
IS2	67	64
IS4	68	51

Manganese appeared to be mostly in the soluble form; only 8% of the samples had less than 50% soluble manganese. Zinc and iron soluble/insoluble data showed much variation; about 37% of the samples had less than 50% soluble zinc and iron.

2.1.2.3 CHEMICAL DISTRIBUTION

Nitrogen oxidation from ammonia to nitrate was seen in Indian Creek downstream of the treatment plant outfall. While most of the non-organic nitrogen at Station IP was in the ammonia phase (average of 64% ammonia, 28% organic nitrogen, 7% nitrate), Station IS5 showed almost opposite ammonia-nitrate fractions (average of 21% ammonia, 30% organic, and 45% nitrate) (Figure 2.2). Mean nitrite fractions also increased downstream, with .8% nitrite at IP to 2.8% at IS5.

Generally most of the soluble phosphorus at each station was in the orthophosphate form. The ratio of orthophosphate to total phosphorus was influenced by the fraction of soluble phosphorus. Station IP showed 50% of the total phosphorus as orthophosphate. The three other main channel stations averaged greater than 85% of the phosphorus as orthophosphate. The two tributary stations showed less predominance of the orthophosphate form; measurement near detection limits caused high variability in the percentage calculations.

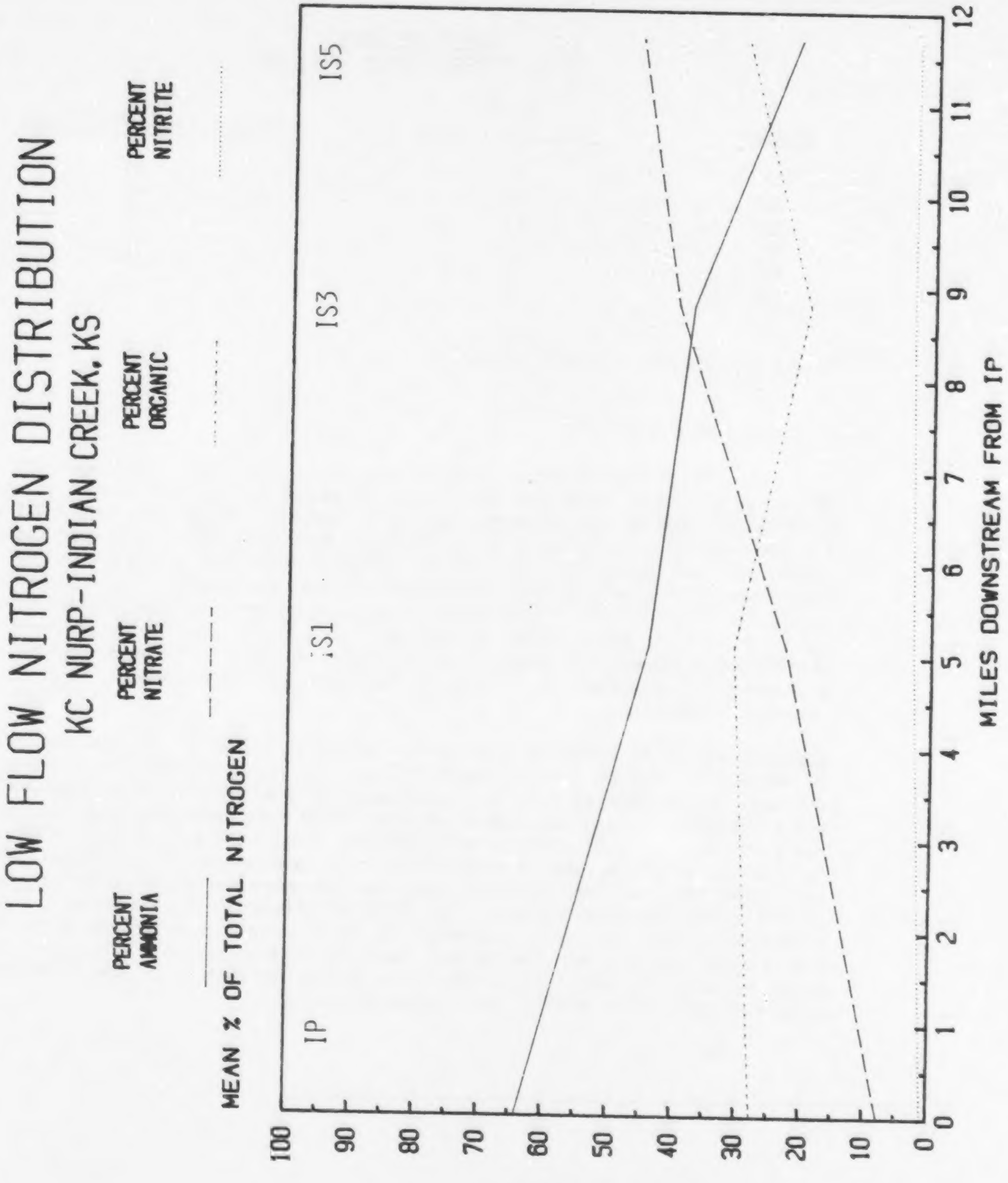
LOW FLOW NITROGEN DISTRIBUTION
KC NURP-INDIAN CREEK, KS
PERCENT AMMONIA
PERCENT NITRATE
PERCENT ORGANIC
PERCENT NITRITE
MEAN % OF TOTAL NITROGEN
IP
IS1
IS3
IS5
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
11
12
MILES DOWNSTREAM FROM IP

FIGURE 2.2

Low Flow Data
Mean Orthophosphate Fractions

Station	% of Total Phosphorus	% of Soluble Total Phosphorus
IP	50	89
IS1	85	91
IS3	91	93
IS5	85	93
IS2	50	117[1]
IS4	25	44[1]

[1] Near analysis detection limits

2.2 WET WEATHER

The Event Mean Concentration (EMC), defined as the total constituent mass discharge divided by the runoff volume, was measured for each parameter through chemical analysis of flow weighted composite samples. These data were used as the basis for statistical analyses requiring normally distributed data with equal variances. Because of this requirement, standard deviations and the descriptive parameters of skewness and kurtosis were calculated to determine the distribution of EMC's. In a normally distributed population, the distribution curve (frequency of occurrance vs. value) is bell shaped and has a single peak about which it is symmetrical. Skewness, a measure of asymmetry around the mean, and kurtosis, a measure of peakedness of the top of the curve, are both close to zero for a normal distribution.

Standard deviation, skewness, and kurtosis were calculated for the chemical data in two ways· with all stations combined, and for each parameter for individual stations. Results showed that the concentration data were not normally distributed since skewness and kurtosis values deviated from zero, and also that standard deviations were very different between stations. The EMC's were then transformed to natural logrithms, and skewness, kurtosis, and standard deviations were calculated both on the combined data set for each parameter and for each parameter by individual station. The combined station analysis showed the log transformed data for each parameter to more closely approximate a normal distribution than the non-transformed data, as summarized in Table 2.5. The same was true for individual station data except for station IP, which displays a normal distribution without the log transformation.

Table 2.5
Characterization of Combined NURP Concentration Data (All Stations)

	No transformation			Log transformation		
Parameter	Stnd. Dev.	Skewness[1]	Kurtosis[2]	Stnd. Dev.	Skewness[1]	Kurtosis[2]
TSS	1184.2	4.2	29.1	0.7	-0.3	-0.5
TP_{tot}	2.2	2.7	8.4	0.5	0.1	-0.4
TP_{sol}	1.7	2.8	7.2	0.6	0.6	-0.1
$OrthoP_{sol}$	1.6	2.9	8.3	0.7	0.7	-0.0
TKN_{tot}	5.6	1.9	3.0	0.5	-0.1	-0.4
TKN_{sol}	4.3	2.7	6.7	0.6	0.5	-0.2
NO_3	0.9	2.9	11.9	0.4	-0.5	1.4
NO_2	0.1	2.3	5.7	0.6	0.4	-0.7
NH_3	4.0	3.2	9.7	0.8	0.4	-0.2
COD	128.1	7.6	78.4	0.4	-1.6	13.0
BOD	12.3	2.8	11.1	0.3	0.2	0.5
Chloride	90.6	6.0	46.0	0.4	0.0	0.3
Specific Conductance	294.1	2.2	7.1	0.3	-0.4	0.3

[1] skewness of normal distribution = 0
[2] kurtosis of normal distribution = 0

While it was found that the combined data set of the concentrations generally fit a log-normal distribution, variation between individual stations for the same parameter was also found. Non-transformed TSS, TPT, and COD concentration data are presented as cumulative frequency distribution plots (percent time value is equaled or exceeded vs. concentration) in Figures 2.3, 2.4 and 2.5, demonstrating variation in the shape of the curve within and between study areas. These plots support evidence from previous studies of urban runoff that considerable variation in concentration exists between nearby stations during the same event and within the same station during successive events.

Three different estimates can be used as an indicator of the central tendency of a data set: the arithmetic mean, the median, and the arithmetic mean of data falling between the upper and lower decile range. The mean is the sum of all values divided by the total number of values comprising the sum. The median is the middle value in a set of data ordered by magnitude. The upper decile is that portion of the observations represented by only 10 percent of the events with the highest values. The lower decile is that portion represented by the lower 10 percent of the events. Comparison of these estimates for application to urban runoff data points out that the mean is sensitive to extreme values, while the median is not. Because the NURP concentration data are log-normally distributed, rare extreme values may be overemphasized when reporting only the arithmetic mean. For this reason, the median was used as the best measure of central tendency to characterize these data. The arithmetic mean of the 10-90 decile range was used to temper the effects of both high and low extreme values.

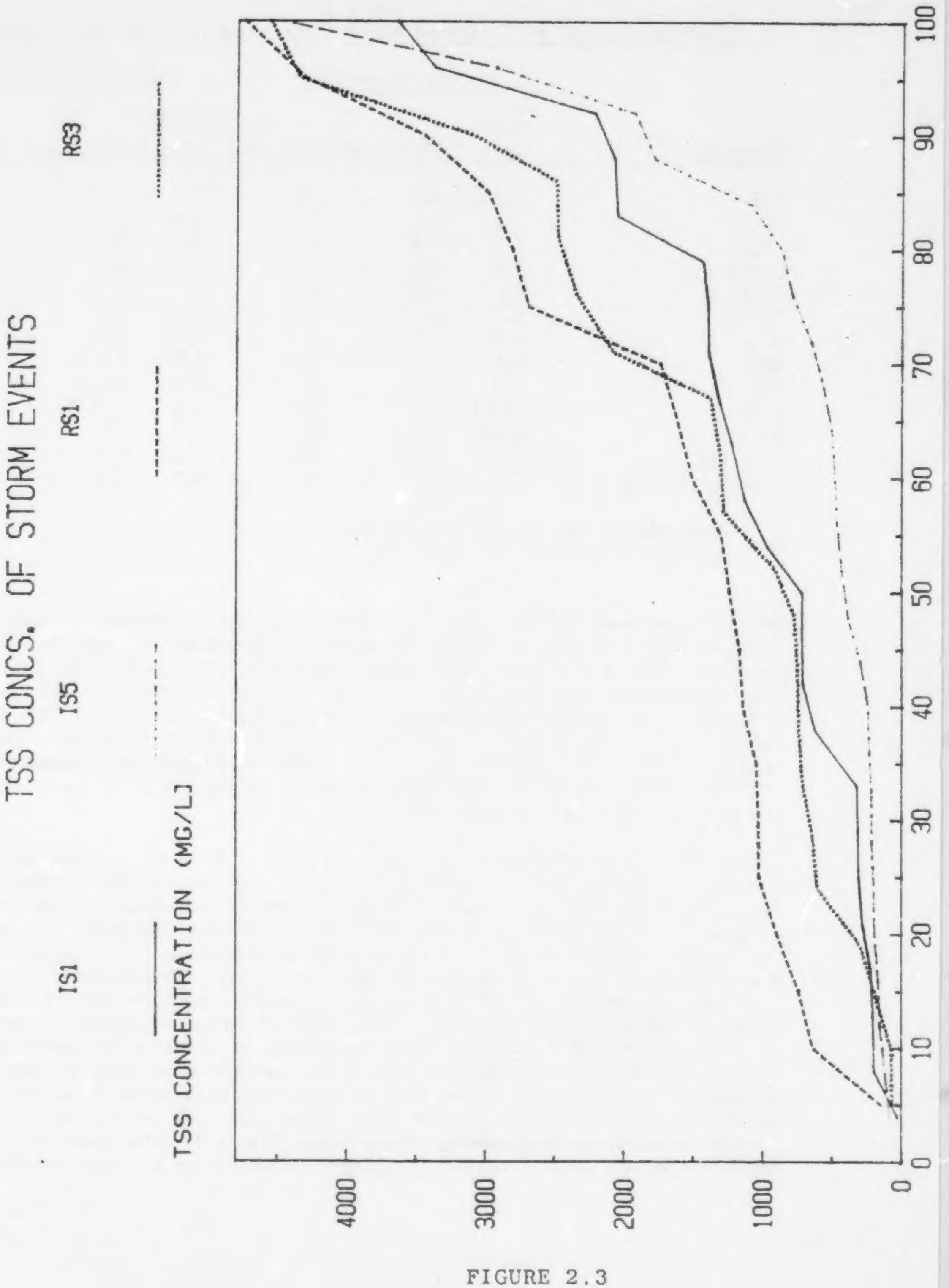
TSS CONCS. OF STORM EVENTS
IS1
IS5
RS1
RS3
TSS CONCENTRATION (MG/L)
0
1000
2000
3000
4000
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2.3

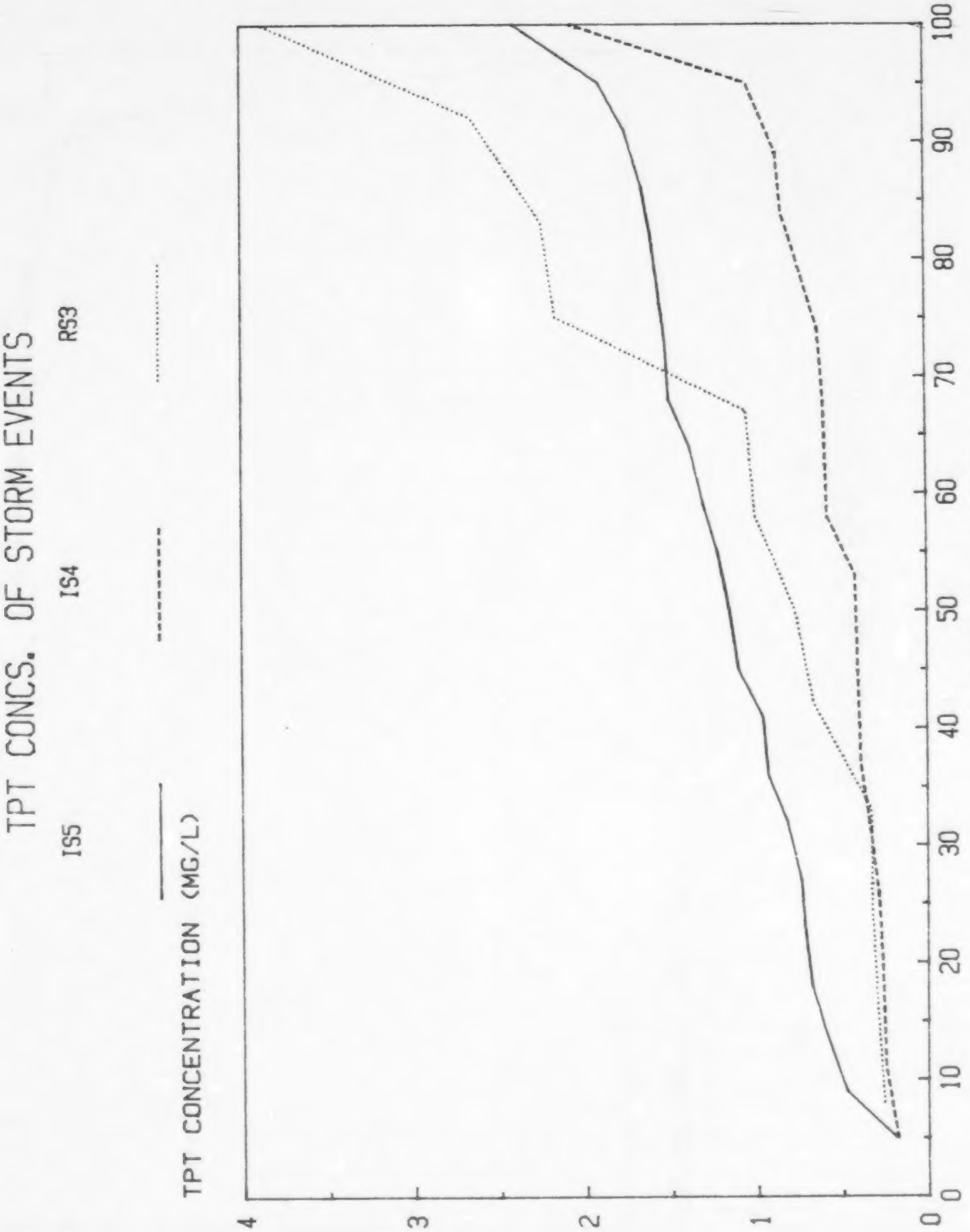
TPT CONCS. OF STORM EVENTS
IS5
IS4
RS3
TPT CONCENTRATION (MG/L)
0
1
2
3
4
% STORMS ≤ VALUE
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2.4

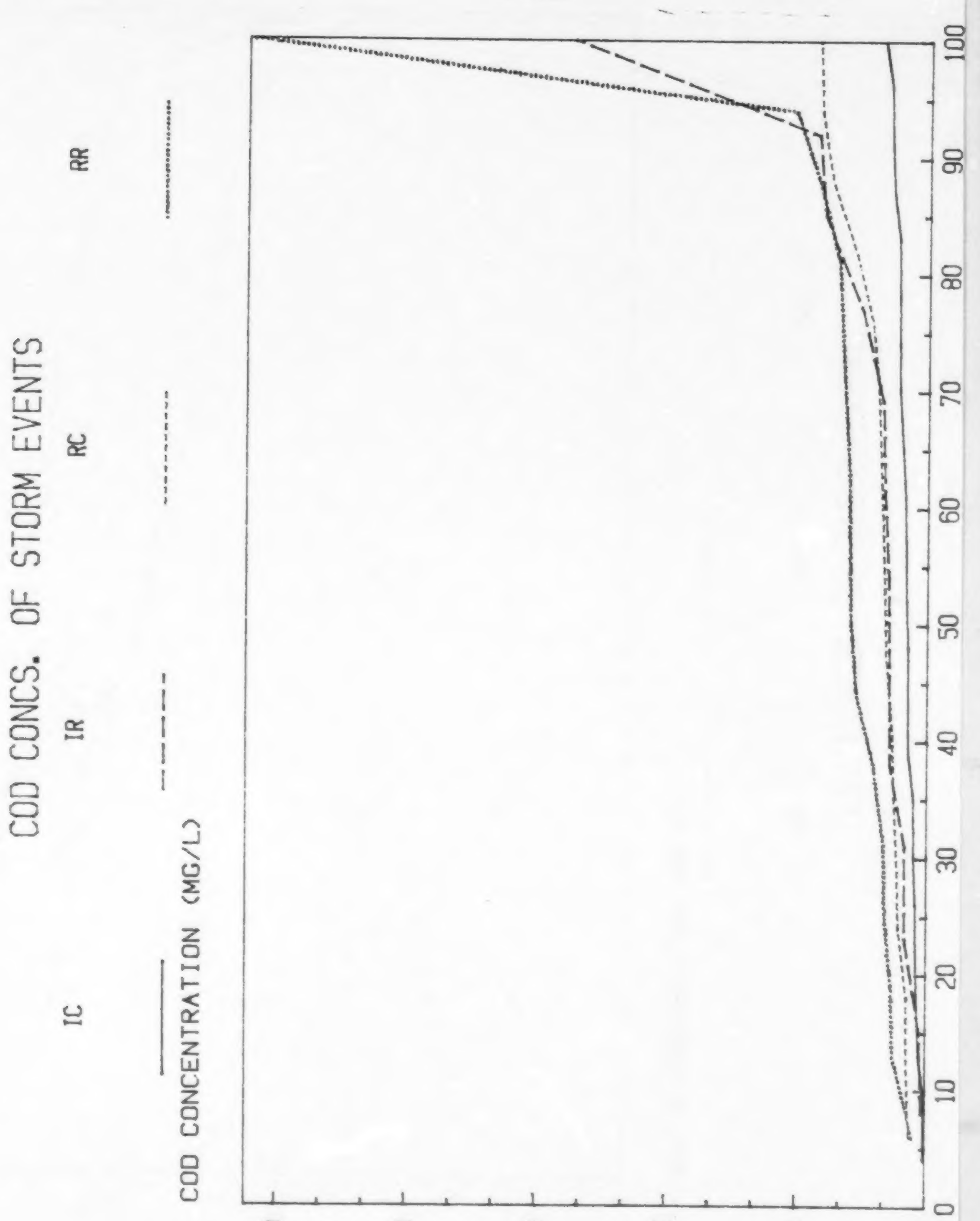
COD CONCS. OF STORM EVENTS
IC
IR
RC
RR
COD CONCENTRATION (MG/L)
1500
1200
900
600
300
0
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2.5

Figure 2.6 demonstrates the differences in interpretation that could result from the inclusion of extreme values to characterize concentration data.

Summaries of concentrations, chemical species distributions, solubilities, toxic scan results and field data are presented in the following sections. The complete data set is included in the appendix of this report. All parameters are characterized by large ranges and relatively high variability. However, several general statements summarize wet weather concentration data:

1. Rock Creek was higher in TSS and oxygen demanding substances than Indian Creek.
2. Indian Creek was higher in nutrients, and there was more variation between stations in the same storm and within stations during different storms than in Rock Creek.
3. Rock Creek nutrient concentrations were more similar to Indian Creek tributary concentrations than they were to Indian Creek stream concentrations.
4. Instream concentrations for the same event in Rock Creek were similar between stations, probably due to the relatively uniform land use in the watershed and the short distance between stations.
5. Of the land use sites, RR usually had the highest pollutant concentrations while IC often had the lowest.

2.2.1 LAND USE SITES WET WEATHER DATA

2.2.1.1 CONCENTRATION SUMMARY

All concentrations are in mg/l and all means are the 10-90 decile mean of the data.

Total Suspended Solids (TSS)

The residential sites from both study areas were higher in TSS than the commercial/industrial sites from the same area. Station RR had a higher median value by an order of magnitude over the other sites.

Station	Median	10-90 decile mean	Range
IC	34	51	6-306
II	59	80	6-257
IR	100	104	47-732
RC	197	223	45-910
RR	1787	1681	62-11,560

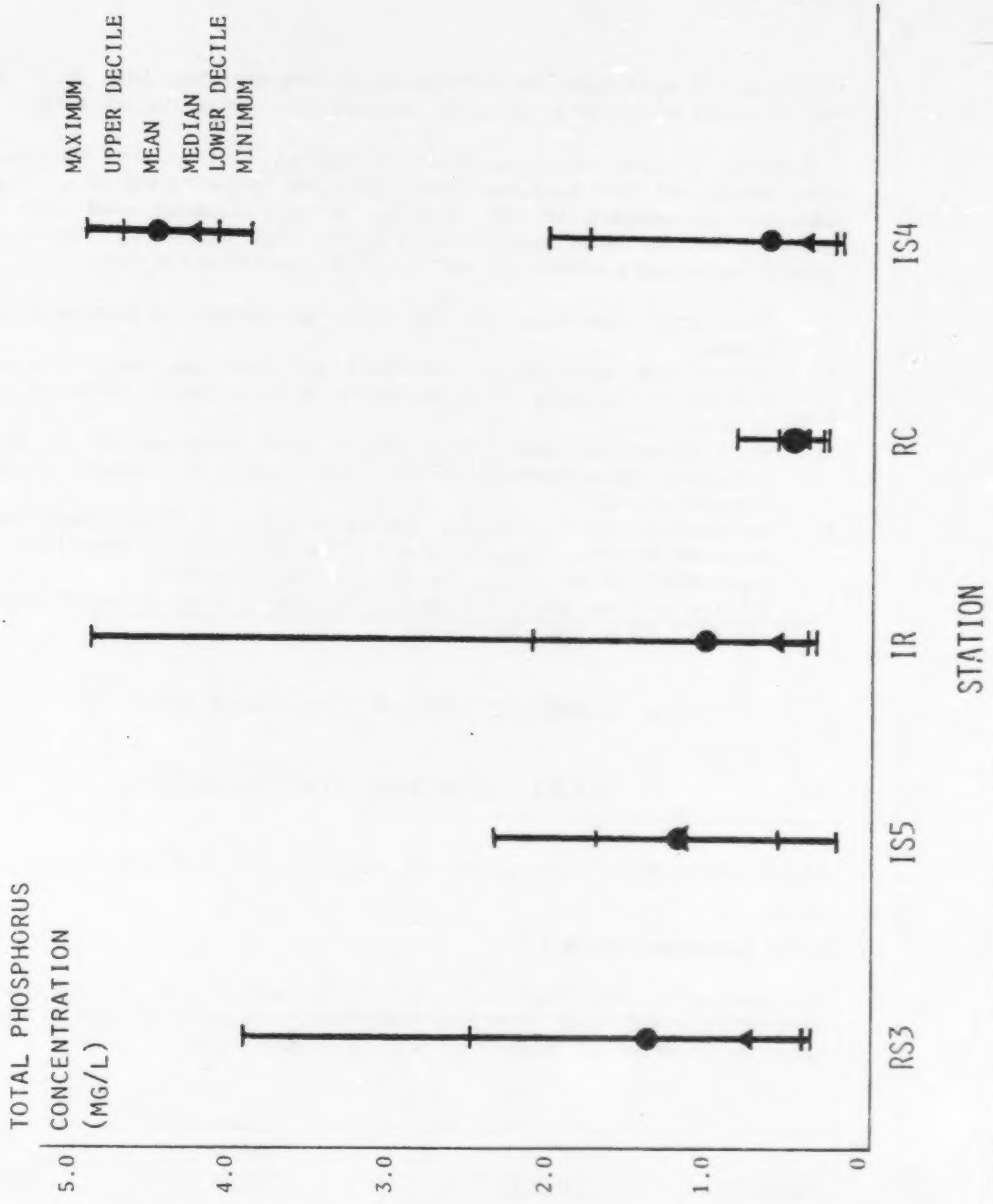

FIGURE 2-6

COMPARISON OF STATISTICAL SUMMARIES

Phosphorus: Total (TPT), Soluble (TPS), Ortho (PO_4)

The residential sites were consistently higher than the commercial/industrial sites in all forms of phosphorus, probably because of lawn fertilizer application. Station RR had the highest TPT concentrations because of the high sediment loads carrying phosphorus.

TPT as P

Station	Median	10-90 decile mean	Range
IC	0.17	0.17	0.05-1.6
II	0.32	0.40	0.10-2.5
IR	0.58	0.71	0.25-4.9
RC	0.46	0.46	0.31-0.88
RR	1.7	1.5	0.24-14.6

TPS as P

Station	Median	10-90 decile mean	Range
IC	0.07	0.09	0.01-0.38
II	0.18	0.18	0.02-1.6
IR	0.22	0.22	0.07-0.44
RC	0.13	0.14	0.06-0.29
RR	0.26	0.29	0.17-0.49

PO_4 as P

Station	Median	10-90 decile mean	Range
IC	0.03	0.04	0.01-1.1
II	0.10	0.08	0.01-1.3
IR	0.16	0.15	0.05-0.36
RC	0.07	0.07	0.04-0.20
RR	0.25	0.24	0.11-0.44

Kjeldahl Nitrogen; Total (TKNT) and Soluble (TKNS)

No TKN concentrations were measured at RC and only 2 were measured at RR. Data from the Indian Creek sites are based on larger sample sizes. The residential sites had the highest concentrations.

TKNT as N

Station	Median	10-90 decile mean	Range
IC	0.80	0.91	0.30-3.4
II	1.1	1.1	0.05-3.6
IR	2.2	2.4	0.29-8.0
RR	--	1.5	0.66-2.3

TKNS as N

Station	Median	10-90 decile mean	Range
IC	0.52	0.49	0.10-1.4
II	0.42	0.35	0.14-0.96
IR	0.84	0.68	0-2.5
RR	----	0.49	0.16-0.82

Nitrate, Nitrite (NO_3, NO_2)

Nitrate concentrations were similar among land use sites except at RR, which had an average concentration over 2 times higher than all other stations. Very low nitrite concentrations were found at all stations. Several high nitrate concentrations at IR were observed during the fertilizer application season (fall).

NO_3 as N

Station	Median	10-90 decile mean	Range
IC	0.46	0.50	0.06-1.1
II	0.32	0.35	0.05-1.9
IR	0.46	0.44	0.02-4.2
RC	0.40	0.39	0.19-1.4
RR	0.89	0.88	0.44-1.3

NO_2 as N

Station	Median	10-90 decile mean	Range
IC	0.02	0.02	0.003-0.12
II	0.01	0.01	0-0.06
IR	0.02	0.02	0.004-0.12
RC	0.02	0.02	0.002-0.08
RR	0.01	0.01	0.003-0.04

Ammonia (NH_3 as N)

The Indian Creek residential site had the highest concentrations of any land use site. This was probably due to heavy application of lawn fertilizers.

Station	Median	10-90 decile mean	Range
IC	0.20	0.32	0-3.5
II	0.10	0.19	0-1.5
IR	0.40	0.40	0-1.8
RC	0.13	0.14	0.02-1.2
RR	0.07	0.08	0.02-0.38

Chloride (Cl^-)

The residential sites had highest mean chloride concentrations. Considerable variability was seen, with IC having the largest range.

Station	Median	10-90 decile mean	Range
IC	11	31	7-160
II	16	18	8-105
IR	27	31	7-83
RC	9	10	2-52
RR	35	32	8-80

Oxygen Demand, Biochemical (BOD) and Chemical (COD)

The Rock Creek sites had higher average concentrations for BOD, while the Indian Creek sites had wider ranges. Rock Creek sites were higher in both average concentrations and ranges for COD.

BOD

Station	Median	10-90 decile mean	Range
IC	7	7	4-86
II	10	10	3-32
IR	19	19	12-60
RC	17	17	9-44
RR	13	13	4-18

COD

Station	Median	10-90 decile mean	Range
IC	48	46	5-106
II	43	49	14-100
IR	89	97	10-818
RC	99	101	37-256
RR	176	155	30-1560

Metals

Lead (Pb), cadmium (Cd), zinc (Zn), sodium (Na), iron (Fe), and manganese (Mn) were analyzed for most storms, usually in both the total and soluble forms.

A detailed discussion of the different types of analysis and detection limits is included in section 1.3.8, "Heavy Metals Analysis." Four different analysis methods were used:

JCUWD 1972 AA Spectrophotometer ("old AA")
JCUWD 1982 AA Spectrophotometer ("new AA")
GTL (General Testing Labs) 1981 Analysis (one storm)
NURP Special Metals Survey (Versar Labs)

The different detection limits of these instruments made analysis of all the data difficult.

Medians and ranges of all but the special metals data are summarized below as total metals in µg/l. GTL data and JCUWD "new AA" data were used in all the summaries; JCUWD "old AA" data were used when a station's metal concentrations were above the "old AA" detection limit. The special metals survey data is discussed in section 2.3.4.

All Heavy metals concenrations are reported in μg/l.

Lead (Pb)

No lead concentration above the 100 μg/l detection limit of the JCUWD "new AA" were found in Indian Creek land use sites. The Rock Creek sites showed median lead concentrations slightly above the detection limit at 130 μg/l.

Station	Median	Range	Number < 100 μg/l - Total Samples
IC	16*	---	8-8
II	7*	---	7-7
IR	---	---	3-3
RC	130	23-374	3-9
RR	130	37-1716	2-9

* GTL sample; detection limit 1 μg/l

Cadmium (Cd)

All but one cadmium sample analyzed by JCUWD were below detection limits. Cadmium data from the one GTL run and summaries from the new JCUWD instrument are listed below.

Station	Median	Range	Number < 10 μg/l Total Samples
IC	2*	< 10	8-8
II	3*	< 10	7-7
IR	--	< 10	3-3
RC	--	< 10	12-12
RR	--	< 10-12	12-13

* GTL sample; detection limit 1 μg/l

Copper (Cu)

Median copper concentrations were higher at the residential sites than the commercial/industrial sites. Data from the new JCUWD and the GTL instrument are shown below.

Station	Median	Range	Number < 30 µg/l Total Samples
IC	17*	< 30-62	4-8
II	30	1-50	3-7
IR	51	44-113	0-3
RC	31	23-71	4-12
RR	88	26-381	1-8

* GTL sample; detection limit 1 µg/l

Zinc (Zn)

Rock Creek sites were higher than Indian Creek sites and residential sites were higher than commercial/industrial sites for both study areas in zinc concentrations. No total samples were found below the detection limit of either JCUWD instrument. Several samples with very high concentrations were found at station II, the light industrial site.

Station	Median	Range	Number of Samples
IC	195	< 10-830	14
II	225	< 10-10,730	9
IR	310	148-2,300	7
RC	350	120-5,500	15
RR	550	121-3,980	14

Sodium (Na)

Median sodium concentrations were variable between stations and study areas; RR had the highest concentrations overall.

Station	Median	Range	Number of Samples
IC	10,050	7,250-92,199	12
II	15,750	6,500-54,399	11
IR	10,700	4,900-78,199	7
RC	5,500	2,150-58,599	15
RR	19,624	5,860-35,399	14

Iron (Fe)

The residential sites from both areas had higher concentrations than the commercial/industrial sites, and Rock Creek sites were higher overall than Indian Creek sites. No total iron samples were found below detection limits.

Station	Median	Range	Number of Samples
IC	520	350-13,500	12
II	2,500	360-18,000	11
IR	4,300	3,090-21,600	7
RC	7,810	700-16,300	14
RR	35,600	437-114,500	13

Manganese (Mn)

As with iron, manganese concentrations at the residential sites from each area were higher than the commercial/industrial sites, and Rock Creek concentrations were higher overall than Indian Creek concentrations. The Indian Creek commercial site had very low manganese concentrations and Station RR had extremely high concentrations.

Station	Median	Range	Samples < 20 µg/l Total Samples
IC	105	17-180	1-8
II	135	60-440	0-11
IR	220	100-590	0-7
RC	258	100-443	0-16
RR	2006	167-11,414	0-14

2.2.1.2 SOLUBLE FRACTION

Total Kjeldahl nitrogen, total phosphorus and the metals were measured in both the total and soluble forms. Mean total and mean soluble values were used to determine the mean percentage soluble fraction.

Kjeldahl Nitrogen

Data are summarized for Indian Creek land use stations only, since Kjeldahl nitrogen was measured only a few times in Rock Creek. Generally 30 to 60 percent of Kjeldahl nitrogen was in the soluble form.

Station	Mean % Soluble Fraction
IC	49
II	53
IR	31

Phosphorus

Phosphorus solubility varied from around 20 to 70 percent at the land use stations, with RR having the lowest soluble fraction and II having the highest.

Station	Mean % Soluble Fraction
IC	49
II	62
IR	42
RC	31
RR	21

Metals

Percentage solubilities for copper, zinc, iron and manganese were highly variable between metals and sites. RR consistently had the lowest soluble percentage, corresponding to the high TSS concentrations measured at that site. Copper was the most soluble metal and iron the least soluble. The greatest variability between sites occurred with zinc solubility. Soluble fractions at Indian Creek sites were higher overall than soluble fractions at Rock Creek sites.

The Indian Creek commercial site had the highest soluble fractions of zinc and copper. This was probably due to the source mechanisms of these metals at IC compared to the other sites: deposition from cars is the key process at IC, while erosion and transport of particulate material is dominant at the other sites.

Station	Mean % Solubility of Metals			
	Cu	Zn	Fe	Mn
IC	85	96	17	32
II	72	19	5	43
IR	63	53	5	52
RC	66	45	6	14
RR	41	17	1	2

2.2.1.3 CHEMICAL SPECIES DISTRIBUTION

Nitrogen

Nitrogen was measured as total and soluble Kjeldahl nitrogen (organic plus ammonia), ammonia, nitrate and nitrite. The total nitrogen concentration was calculated by adding total Kjeldahl nitrogen, nitrate and nitrite for the Indian Creek stations; complete data were not available for Rock Creek stations. The distribution of nitrogen in the above forms for Indian Creek land use stations is shown below:

Mean % of Total Nitrogen

	IC	II	IR
Organic	42	43	53
NH_3	23	24	19
NO_3	33	32	27
NO_2	2	1	1

Total nitrogen distribution was constant between the land use stations with about 50% of the nitrogen in the organic form,and about 20% ammonia. The remaining 30% of total nitrogen was in the nitrate form, with nitrite percentages consistently less than 2% of the total nitrogen distribution.

Phosphorus

Phosphorus was measured as total and soluble total phosphorus and as soluble orthophosphate. The percentage of phosphorus in the soluble form was discussed in the previous section, where it was found that phosphorus solubility varied between 20% and 60% at the land use sites. Orthophosphate was also measured in the soluble form and is summarized below as the percent of total soluble phosphorus as orthophosphate. Approximately 55% to 85% of the soluble phosphorus was in the orthophosphate form, with RR having the highest percent, and residential sites in general having higher percentages of soluble phosphorus as orthophosphate.

Mean % Soluble Phosphorus as Orthophosphate

Station	IC	II	IR	RC	RR
	54	55	75	65	88

2.2.1.4 BOD/COD RATIO

BOD/COD ratios are used in industrial applications to characterize the source of oxygen demand as either predominately simple organic waste (high ratio), predominately complex organic waste (low ratio), or mixed waste. All ratios from land use sites were low, reflecting that COD concentrations were usually higher than BOD concentrations. Extrapolation of these ratios to urban runoff data may indicate toxic effects on the bacteria, since none of these sites have runoff containing complex organic waste.

	BOD/COD Ratio				
Station	IC	II	IR	RC	RR
	.15	.23	.21	.17	.07

2.2.1.5 TOXIC SCAN RESULTS

NURP study sites were sampled for priority pollutants through participation in the toxic scan element of the nationwide study. Land use catchments from several NURP projects across the country were sampled to determine the presence and magnitude of priority pollutants in urban runoff.

Several events at stations IC, II, RR and RC were grab sampled in November 1981 and July and August 1982. Table 2.6 describes key characteristics of these events. Section 1.3.6.5 describes the collection procedure: once collected, samples were preserved and transported to the regional EPA laboratory for analysis. An attempt was made to collect one first flush sample, one sample near peak flow, and one sample representing the lower portion of the hydrograph from each catchment. This was accomplished for IC and II; for RR and RC, only the first flush and peak samples were obtained. The samples representing these distinct portions of the hydrograph were not necessarily collected during the same storm, resulting in limited specific information. Table 2.7 presents a summary of the occurrence of four of the major groups of priority pollutants: organics, cyanide, phenolics, and metals. For the metals, only those detected in one or more samples are listed. Organics are shown as a group and not broken down by compound. Table 2.8 summarizes the range of concentrations of the priority pollutants found from all sites.

Table 2.6
Key Characteristics of Storms Sampled
For Priority Pollutants

Station	IC	IC	IC	II	II	RC	RR	IC
Sample type	first flush	peak	post peak	first flush	peak	peak	first flush	post peak
Date	8/12/82	8/12/82	8/12/82	8/12/82	8/12/82	8/12/82	8/12/82	7/1/82
Collection Method	Grab	Grab	Grab	Grab	Grab	Grab	Grab	Grab
Start of Storm	1025	1025	1025	1035	1035			1645
Time of Peak	1040	1040	1040	1057	1057			1720
End of Storm	1300	1300	1300	1400	1400			2000
Sample Collection Time	1030	1037	1050	1047	1057	1340	1350	1930
Flow during sampling (cfs)	3.3	5.8	3.1	0.4	17	2-5	2	0.8
Event Peak Flow (cfs)		6.0		17				9.6
Precipitation for event (in.)		.25		.19				.27
Est. precipitation intensity (inches/hr)		1.0		2.3				.53
NOTES		precipitation values from Corporate Woods raingage		sample 25% base flow		VOA's taken near 1600		

Table 2.7
Occurrence of Priority Pollutants at Land Use Sites

	IC				II			RC		RR	
DATE	1st Flush 8/12/82	Peak 8/12/82	Post Peak 8/12/82	Post Peak 7/1/82	1st Flush 8/12/82	Peak 8/12/82	PostPeak 7/1/82	1st Flush 7/6/82	Peak 8/12/82	1st Flush 8/12/82	Peak 11/30/81
ORGANICS	*	*	*	*	*	*	*	*	*	*	*
CYANIDE				**			**				
PHENOLICS	**	**	**	**	**	**	**	**	**	**	**
ALUMINUM#	*	*	*	*	*	*		*	*	*	*
CHROMIUM	*	*	*			*				*	
BARIUM	*	*	*		*	*		*		*	*
CADMIUM	*	*		*	*	*			**		
COPPER	*	*	*		*	*		*		*	*
IRON	**	**	*	*	**	**	*	*	**	**	**
LEAD	**	**	**	**	*	**	*	*	**	*	*
NICKEL	*	*	*		*	*		*			*
MANGANESE	**	**	*	*	**	**	*	*	**	**	**
ZINC	*	*	*	*	*	*	**	*	*	*	*
ARSENIC	*	*	*		*	*					*
MERCURY	**	**	**	*	**	**	*		*		
COBALT#	*	*				*					*
VANADIUM#	*	*	*		*	*		*			*
TIN#								*			
SELENIUM									*		
CALCIUM#										*	
MAGNESIUM#										*	
SODIUM#										*	

no quality criteria established
* detected

** concentration greater than quality criteria

TABLE 2.8
EPA QUALITY CRITERIA (μg/l) and RANGES (μg/l) of PRIORITY POLLUTANTS FOUND AT LAND USE CATCHMENTS

POLLUTANT	CRITERIA	LOW	HIGH
Cyanide	5.0	5.0	5.5
Phenolics	1.0	11.0	33.0
Aluminum	--	18.0	3460
Chromium	50	12	21
Barium	1000	17	76
Cadmium	10	1	11
Copper	1000	5	33
Iron	1000	420	5360
Lead	50	10	360
Nickel	--	4	11
Manganese	50	28	220
Zinc	5000	33	700
Arsenic	50	1	10
Mercury	2	0.21	2.8
Cobalt	--	1	2
Vanadium	--	3	11
Tin	--	--	18
Selenium	10	--	3
Calcium	--	--	25
Magnesium	--	--	3
Sodium	--	--	7

Organics, phenolics, iron, lead, manganese, and zinc were the pollutants most commonly detected and were found in the highest concentrations. Phenolics were not associated with any particular limb of the storm and were always found in concentrations exceeding the quality criteria for all land uses. Iron occurred in the highest concentrations in the beginning of storms with concentrations declining during the tail end of storms. The pattern of lead occurrence was similar to the phenols, but concentrations were much lower at the residential site than at the commercial/industrial sites. The high concentrations of manganese were generally distributed throughout the hydrographs; in this case RR had substantially higher concentrations than the other sites. Zinc concentrations at all sites showed a pattern of occurring in higher concentrations during the peak portion of the storm than during the first flush, and the Indian Creek sites were much higher than the Rock Creek sites.

The Indian Creek commercial site, IC, was the only one in which a complete series representing the first flush, peak, and tail end of the hydrograph during the same storm was obtained. These were collected during August of 1982 and represent a small intense storm lasting about 2 hours from the beginning to the end of the runoff. A detailed account of phenolics and metals concentrations measured at this site is presented below:

PRIORITY POLLUTANT CONCENTRATIONS
at IC DURING AUGUST 12, 1982 STORM
(µg/l)

Pollutant	First Flush	Peak	Post Peak
Phenolics	12	15	11
Aluminum	1500	1640	491
Chromium	17	21	12
Barium	29	25	17
Cadmium	4	4	
Copper	14	20	10
Iron	2080	2180	699
Lead	220	210	70
Nickel	6	8	8
Manganese	64	53	28
Zinc	375	465	203
Arsenic	4	2	1
Mercury	2.4	2.4	2.6
Cobalt	1	1	
Vanadium	5	6	3

Pollutants exhibited one of two major patterns: 1) concentrations stayed relatively constant during runoff; or 2) concentrations declined through the duration of the storm. The first pattern was seen with phenolics, cadmium, nickel, mercury, and cobalt. The second pattern was more common for aluminum, chromium, barium, copper, iron, lead, manganese, zinc, arsenic, and vanadium.

2.2.2 ROCK CREEK WET WEATHER DATA

2.2.2.1 CONCENTRATION SUMMARY

Rock Creek chemical concentration data were usually very similar between stream stations during the same storm, but a high degree of variability was seen between storms for most parameters. TSS, TPT, and COD showed more variability between stations than the other parameters; as in Indian Creek, concentrations were lower for the downstream stations. TSS, TPT and COD concentration frequency plots are presented in Figures 2.7, 2.8 and 2.9, demonstrating the pattern of the concentrations at RS1, RS2 and RS3 for these parameters.

Concentration data for RS1 and RS3 are summarized with medians, 10-90% decile means and ranges in this section. RS2 data generally corresponded to the data although fewer storms were sampled at this site. The complete data base is in the appendix to this report.

Concentration Data Summary (mg/l)

Parameter	Station	Median	10-90 decile mean	Range
TSS	RS1	1241	1475	145-4752
	RS3	915	1122	71-4567
TPT as P	RS1	1.1	1.2	0.33-3.1
	RS3	0.77	0.98	0.26-3.9
TPS as P	RS1	0.11	0.13	0.08-0.24
	RS3	0.12	0.12	0.06-0.26
PO_4 as P	RS1	0.09	0.09	0.05-0.27
	RS3	0.09	0.09	0.04-0.23

TKNT as N	RS1	--	0.73	0.11-5.0
(3 samples)	RS3	--	1.5	0.45-4.4
TKNS as N	RS1	--	0.49	0.18-0.52
(3 samples)	RS3	--	0.99	0.43-1.5
NO_3 as N	RS1	0.69	0.68	0.24-0.94
	RS3	0.67	0.68	0.33-1.3
NO_2 as N	RS1	0.02	0.02	0.01-0.03
	RS3	0.01	0.01	0-0.02
NH_3 as N	RS1	0.08	0.09	0.01-1.1
	RS3	0.06	0.08	0.01-1.2
BOD	RS1	17	16	8-21
	RS3	15	15	4-25
COD	RS1	123	129	40-247
	RS3	113	111	20-279
CL^-	RS1	48	44	20-102
	RS3	48	57	18-106

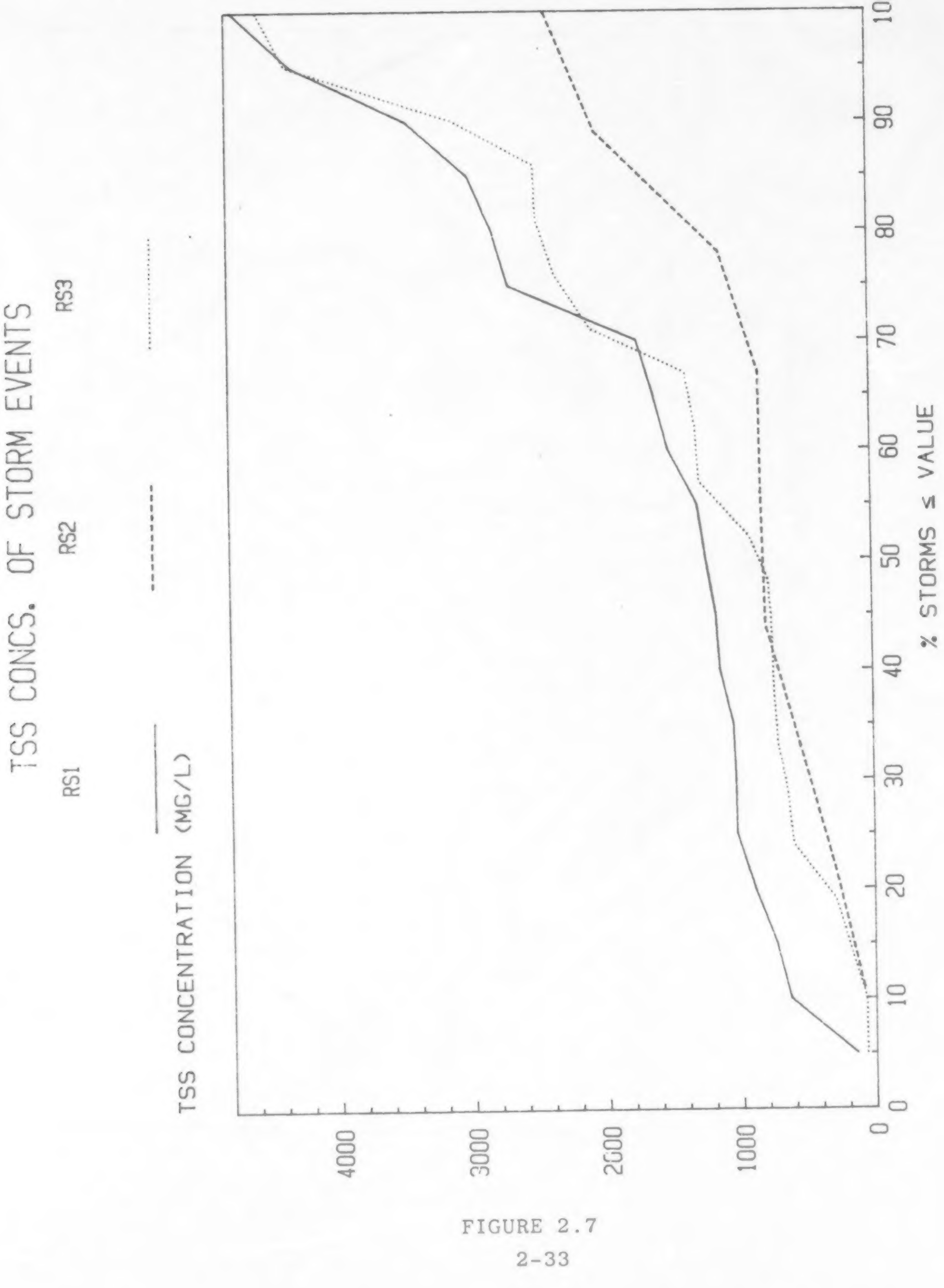
TSS CONCS. OF STORM EVENTS
RS1
RS2
RS3
TSS CONCENTRATION (MG/L)
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
% STORMS ≤ VALUE

FIGURE 2.7

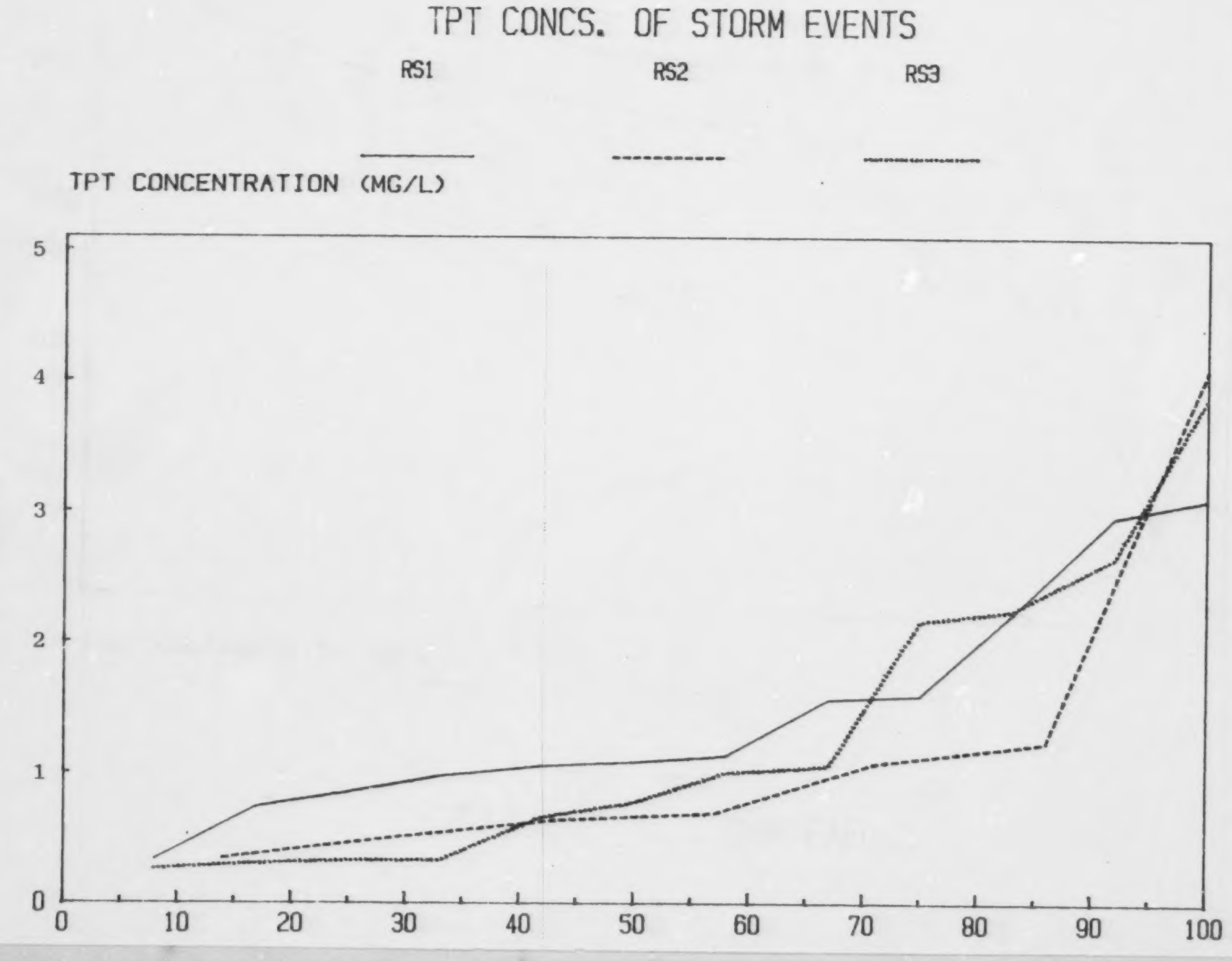
TPT CONCS. OF STORM EVENTS
RS1
RS2
RS3
TPT CONCENTRATION (MG/L)
0
1
2
3
4
5
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2.8

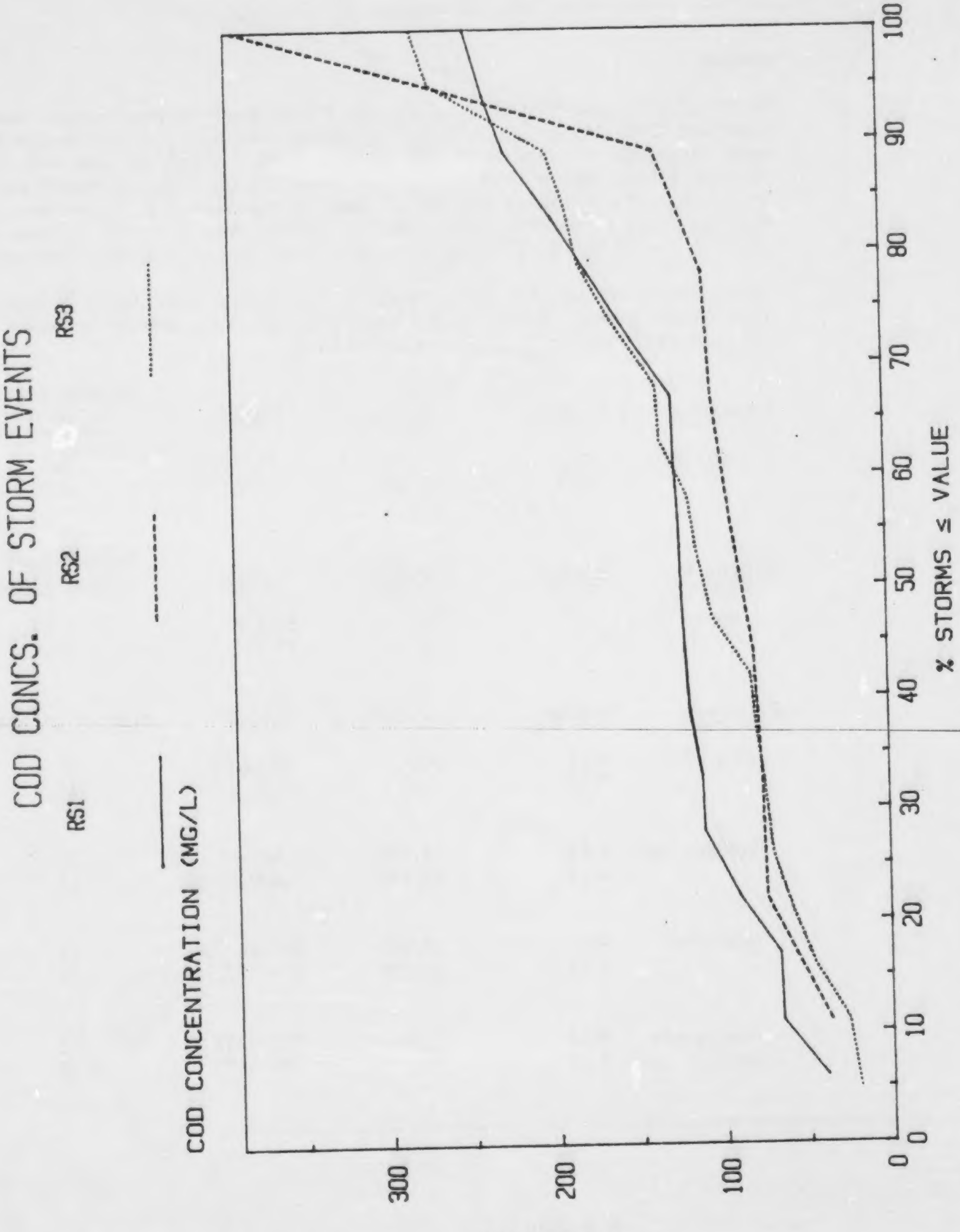
COD CONCS. OF STORM EVENTS
RS1
RS2
RS3
COD CONCENTRATION (MG/L)
0
100
200
300
0
10
20
30
40
50
60
70
80
90
100
% STORMS ≤ VALUE

FIGURE 2.9

Metals

Section 2.2.1.1 and Section 1.3.8 discuss metals analysis procedures. Lead (Pb), Cadmium (Cd), Copper (Cu), Zinc (Zn), Sodium (Na), Iron (Fe) and Manganese (Mn) were measured in both total and soluble form. Cadmium was not found in concentrations higher than detection limits (10 µg/l for cadmium) and is not included in the following summary. Some of the lead and copper samples were measured below detection limits of the JCUWD "new AA"; the number of these samples are listed. No GTL analyses, with lower detection limits, were performed.

Higher lead and slightly higher zinc concentrations were found in Rock Creek than Indian Creek. Other metals concentrations were similar between the two study areas. Metals data are reported in µg/l.

Parameter	Station	Median	Range	Number < 100 µg/l - Total Samples
Lead (Pb)	RS1	< 100	< 100-484	4-9
	RS3	< 100	< 100-572	6-9

Parameter	Station	Median	Range	Number < 30 µg/l - Total Samples
Copper (Cu)	RS1	73	27-176	2-10
	RS3	70	33-748	0-11

Parameter	Station	Median	Range	Number of Samples
Zinc (Zn)	RS1	600	142-3200	15
	RS3	438	< 10-1250	16
Sodium (Na)	RS1	26,700	8,500-264,500	16
	RS3	27,124	7,800-45,200	16
Iron (Fe)	RS1	30,500	298-88,300	16
	RS3	39,000	534-100,750	16
Manganese (Mn)	RS1	1110	177-3213	16
	RS3	876	238-6280	16

2.2.2.2 SOLUBLE FRACTIONS

Kjeldahl nitrogen and total phosphorus were measured in both the total and soluble forms. Based on limited Kjeldahl nitrogen data, 65% of the organic nitrogen was in the soluble form for both RS1 and RS3.

Total phosphorus solubilities are based on larger samples sizes and were calculated from median total phosphorus and total soluble phosphorus concentrations. Phosphorus solubility varied from an average 6% soluble phosphorus at RS1 to an average of 24% soluble phosphorus at RS3. These percentages correspond closely with ratios at the Rock Creek land use sites.

Copper, zinc, iron and manganese were measured in both total and soluble forms. Most of the iron and manganese were insoluble; copper and zinc soluble fractions varied between sites.

Rock Creek Metal Solubilities
Mean % Soluble

	RS1	RS3
Cu	59	22
Zu	18	77
Fe	2	3
Mn	6	4

As with the land use sites, the greatest variability in soluble fraction was seen in zinc concentrations, but the variability was even more pronounced in the stream stations.

2.2.2.3 CHEMICAL SPECIES DISTRIBUTION

Calculation of the total nitrogen distribution in Rock Creek is based on limited data for Kjeldahl nitrogen, but in general, 50-70% of the nitrogen was Kjeldahl nitrogen, 30-45% was in the nitrate form, and less than 1% was nitrite.

Phosphorus distributions are based on more data and were calculated from median phosphorus concentrations. Total soluble phosphorus varied from 16% at RS1 to 24% at RS3. Of this soluble fraction, an average of 70% was in the orthophosphate form. This indicates that while most of the phosphorus in Rock Creek was attached to sediment, the soluble phosphorus that was found was mostly in the readily available orthophosphate form.

Phosphorus/nitrogen ratios were calculated and all stations had a ratio of approximately 1P:1N, during most storms. This indicates that Rock Creek runoff would create a nitrogen limited condition for aquatic flora, as the plant phosphorus:nitrogen ratio is 1:7.

2.2.2.4 FIELD DATA

Based on dissolved oxygen measurements during four storms in Rock Creek, mean D.O. concentrations ranged from 8.2 mg/l to 7.4 mg/l. pH values were fairly constant between stations and the creek as a whole had a mean pH of 6.9 with a range of 6.2-7.8.

2.2.3 INDIAN CREEK WET WEATHER DATA

More variability between stations during the same event was seen for Indian Creek than for Rock Creek, especially for the nutrient parameters. TSS, COD and TPT wet weather concentration frequency plots are presented in Figures 2.10, 2.11, and 2.12, demonstrating the differences in frequency distributions found in the Indian Creek stream and tributary stations.

This discussion of concentrations in Indian Creek focuses on two main channel stream stations: IS1, which is located at the beginning of the urbanized area, and IS5, which is the station furthest downstream and receives runoff from large urban areas. Also summarized are concentration data for IS2 and IS4, which are tributary stations draining into Indian Creek between IS1 and IS5. IS2 drains a mixed light industrial/residential area; IS4 drains a predominantly residential area. Substantial differences in concentration were found between the stream and tributary stations, with the stream stations usually having greater variability and higher concentrations than the tributaries. The tributaries, which receive no point source discharge, were generally more similar to the Rock Creek stream sites and to each other than they were to the Indian Creek stream sites.

This section summarizes concentration data in mg/l for IS1, IS5, IS2 and IS4 with medians, 10-90% decile means, and ranges. The complete data set is in the appendix to this report.

2.2.3.1 CONCENTRATION SUMMARY

Total Suspended Solids (TSS): Median and mean values for TSS overlap between these stations but the tributary stations had smaller ranges and the extreme high concentrations were not seen. IS1 had a higher average concentration that IS5, probably due to agricultural runoff upstream of the station that was diluted as it moved downstream. Urban runoff from stations IS2 and IS4 had significantly lower TSS concentrations than IS1.

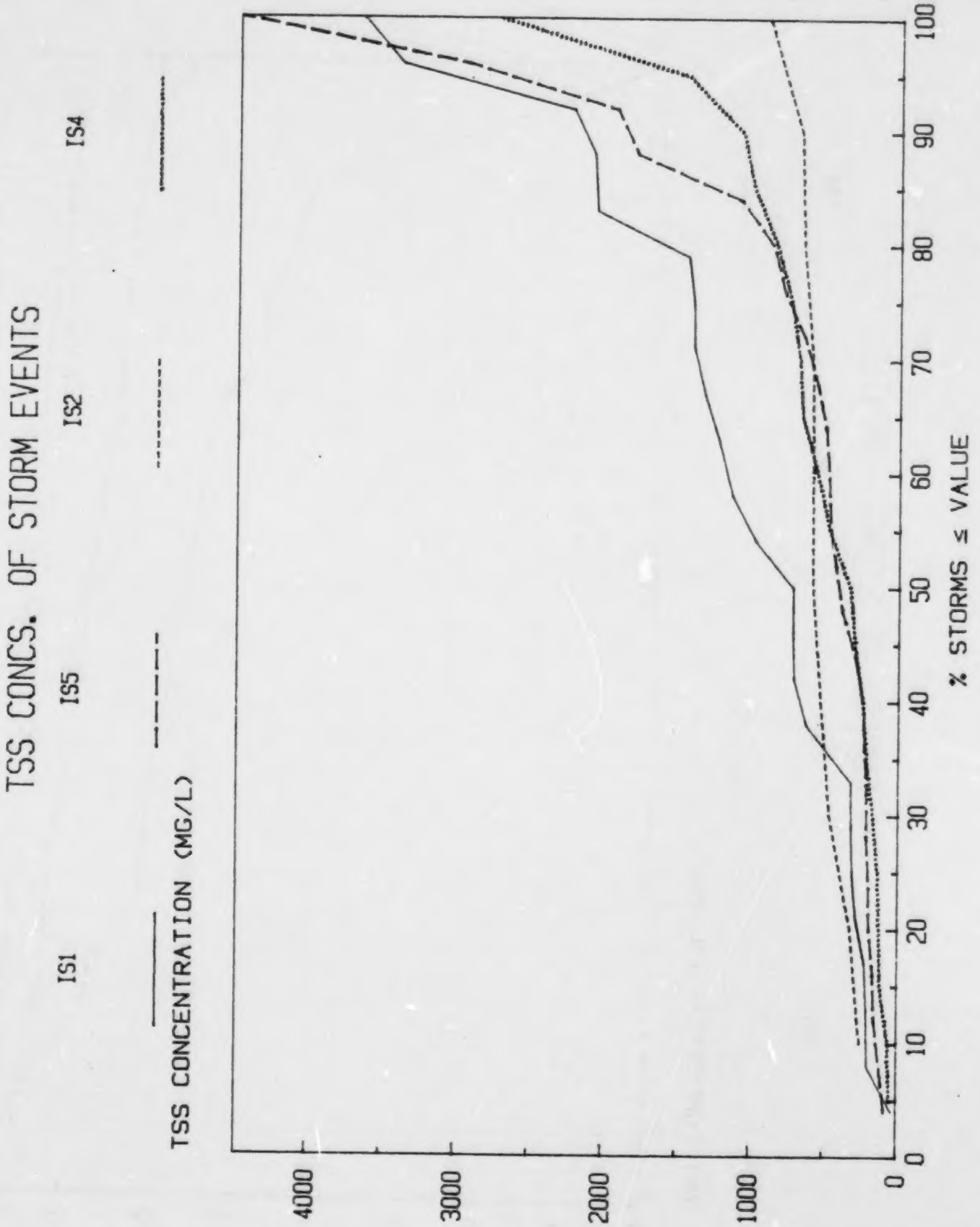
TSS CONCS. OF STORM EVENTS
IS1
IS5
IS2
IS4
TSS CONCENTRATION (MG/L)
0
1000
2000
3000
4000
0
10
20
30
40
50
60
70
80
90
100
% STORMS ≤ VALUE

FIGURE 2.10

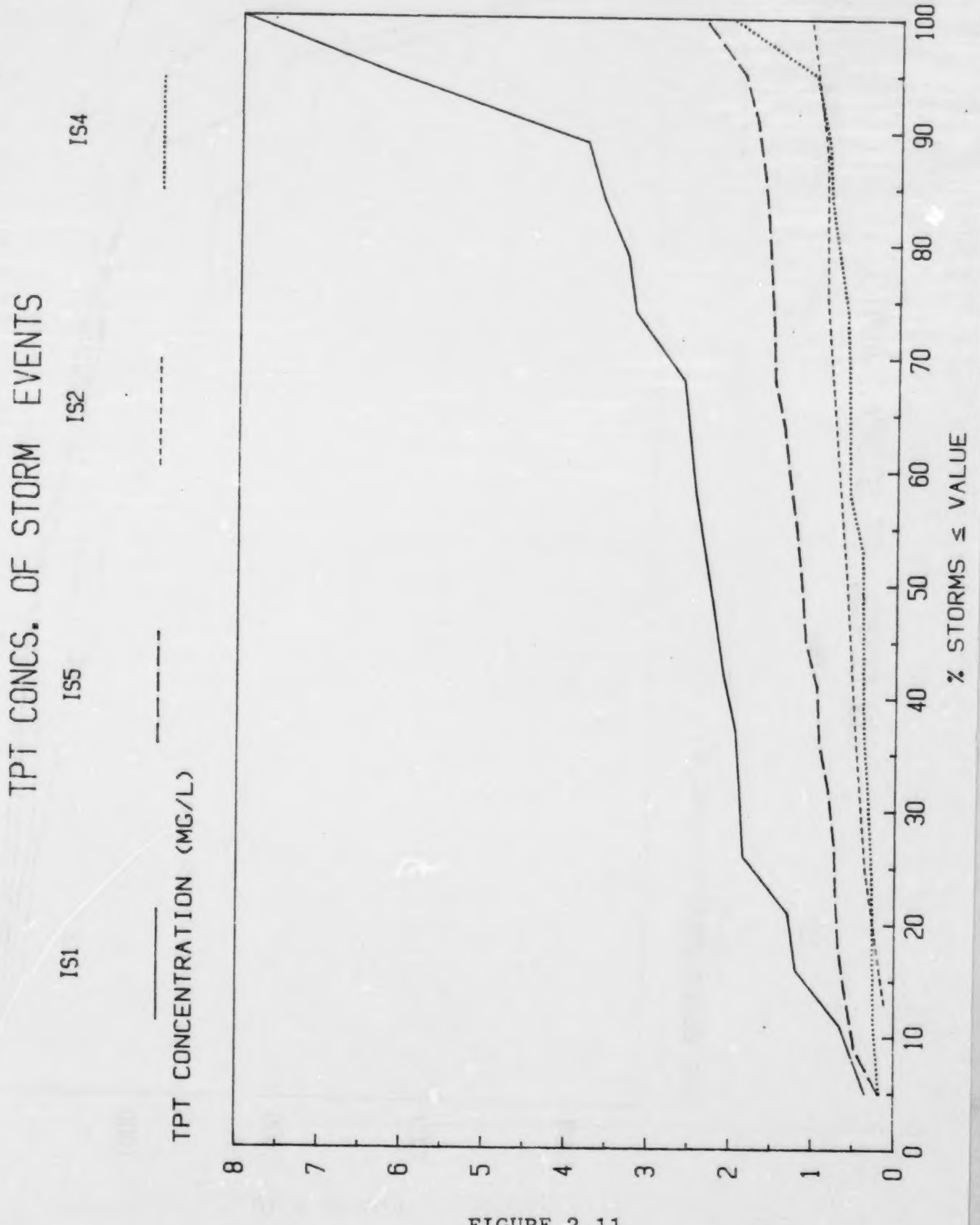
TPT CONCS. OF STORM EVENTS
IS1
IS5
IS2
IS4
TPT CONCENTRATION (MG/L)
0
1
2
3
4
5
6
7
8
% STORMS ≤ VALUE
0
10
20
30
40
50
60
70
80
90
100

FIGURE 2.11

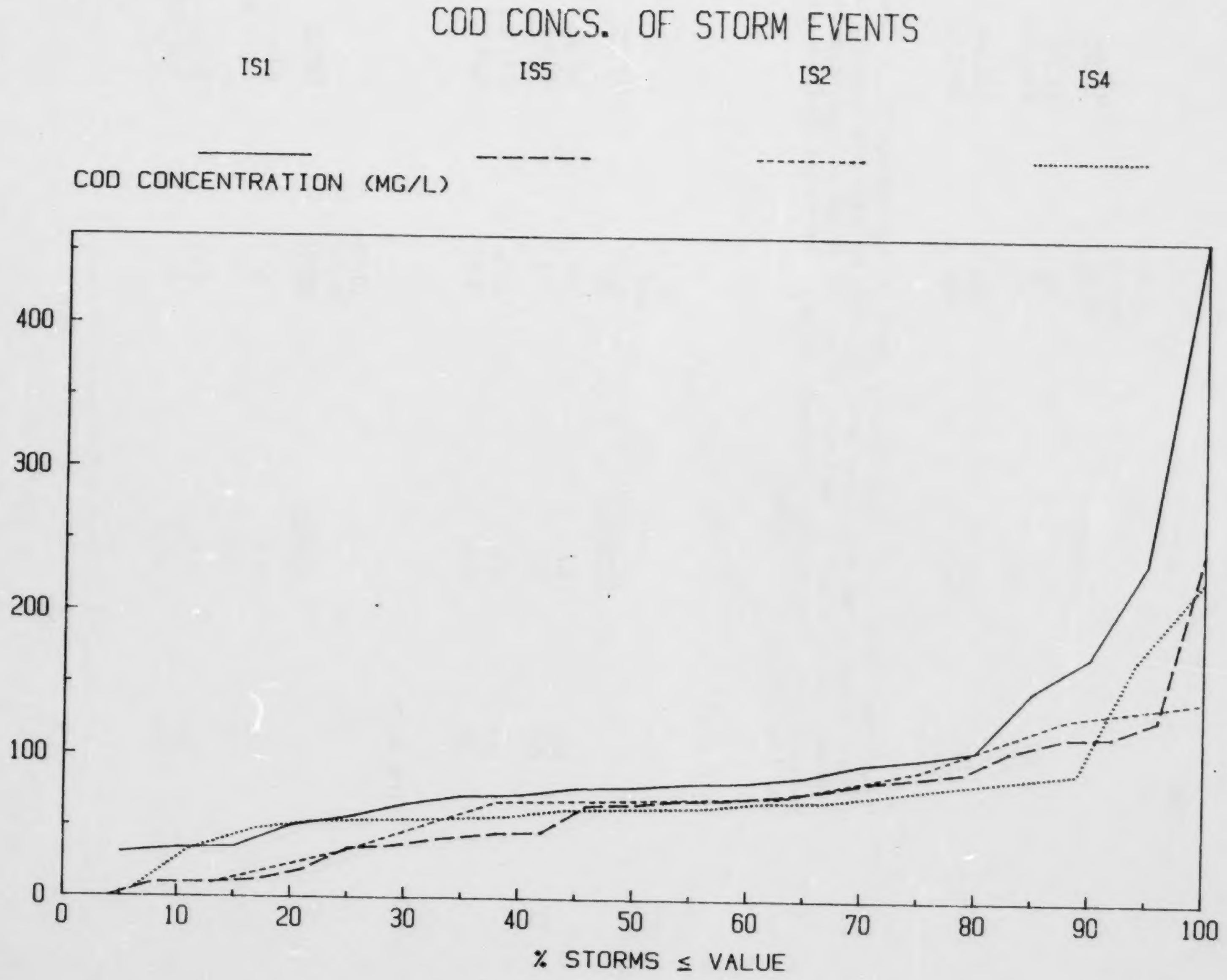
COD CONCS. OF STORM EVENTS
IS1
IS5
IS2
IS4
COD CONCENTRATION (MG/L)
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
% STORMS ≤ VALUE

FIGURE 2.12

TSS

	Median	10-90 decile mean	Range
IS1	718	918	32-3,647
IS5	431	479	83-4,472
IS2	584	550	250-896
IS4	332	436	50-2,717

Phosphorus: Total (TPT), Total Soluble (TPS), Orthophosphate (PO_4). Average concentrations for all phosphorus forms decreased by about 50% from IS1 to IS5. Tributary sites had half as much total phosphorus as stream sites, probably due to the absence of point source phosphorus influence (discharges during wet weather and from dry weather settling).

TPT as P

	Median	10-90 decile mean	Range
IS1	2.4	2.9	0.35-8.0
IS5	1.2	1.1	0.19-2.4
IS2	0.61	0.56	0.12-1.1
IS4	0.42	0.48	0.18-2.1

TPS as P

	Median	10-90 decile mean	Range
IS1	0.71	0.88	0.09-7.5
IS5	0.42	0.47	0.05-1.8
IS2	0.06	0.05	0.02-0.24
IS4	0.09	0.09	0.02-0.38

PO_4 as P

	Median	10-90 decile mean	Range
IS1	0.67	0.97	0.07-7.0
IS5	0.38	0.45	0.10-2.8
IS2	0.03	0.03	0.01-0.07
IS4	0.07	0.07	0.02-0.15

Kjeldahl Nitrogen: Total (TKNT) and Soluble (TKNS). As with phosphorus, organic nitrogen concentrations decreased on the average from IS1 to IS5, and tributary stations had lower average concentrations and smaller ranges.

TKNT as N

	Median	10-90 decile mean	Range
IS1	5.8	6.2	2.8-14.2
IS5	2.7	2.8	0.23-8.8
IS2	1.8	1.4	0.24-5.3
IS4	1.5	1.4	0.04-4.4

TKNS as N

	Median	10-90 decile mean	Range
IS1	3.0	2.2	0.20-9.1
IS5	0.92	0.93	0.001-2.4
IS2	0.58	0.57	0.13-1.3
IS4	0.48	0.44	0-1.5

Nitrate, Nitrite (NO_3, NO_2)

Nitrate concentrations tended to decrease from IS1 to IS5, but the magnitude of the decrease was smaller than for organic nitrogen. Tributary concentrations were 2 to 3 times lower than stream concentrations. Nitrite concentrations decreased by about 60% overall from IS1 to IS5; tributary concentrations were again lower than streams.

NO_3 as N

	Median	10-90 decile mean	Range
IS1	1.7	1.9	0.30-3.4
IS5	1.2	1.3	0.05-2.4
IS2	0.49	0.47	0.37-0.98
IS4	0.49	0.55	0.29-6.8

NO_2 as N

	Median	10-90 decile mean	Range
IS1	0.27	0.24	0.07-0.76
IS5	0.08	0.08	.007-0.40
IS2	0.02	0.01	0.005-0.03
IS4	0.03	0.03	0.006-0.14

Ammonia (NH_3-N)

The same trends observed for organic nitrogen, nitrate, and nitrite were also seen in ammonia concentrations.

	Median	10-90 decile mean	Range
IS1	1.0	1.4	0.05-3.9
IS5	0.50	0.46	0-3.2
IS2	0.21	0.18	0.10-0.30
IS4	0.20	0.18	0-0.50

Oxygen Demand (BOD, COD)

Median biochemical oxygen demand concentrations decreased somewhat from IS1 to IS5, but not to the extent seen for the nutrient parameters. Tributary stations had slightly lower BOD concentrations on the average, but similar ranges.

BOD

	Median	10-90 decile mean	Range
IS1	14	15	10-26
IS5	12	12	7-16
IS2	10	10	8-12
IS4	10	10	7-22

COD

	Median	10-90 decile mean	Range
IS1	78	82	31-461
IS5	67	60	2-243
IS2	70	67	10-141
IS4	63	64	5-225

Chloride (Cl^-)

Chloride was the least variable parameter between stream and tributary stations. The major difference was that the tributaries had lower ranges and extreme values. No relation to season was observed, although stations were shut down from December to April, the main salt application season.

	Median	10-90 decile mean	Range
IS1	38	39	15-129
IS5	38	46	12-300
IS2	31	29	26-42
IS4	31	30	8-103

Metals

Section 2.2.1.1 and Section 1.3.8 discuss metals analysis methods. Lead (Pb), Cadmium (Cd), Copper (Cu), Zinc (Zn), Sodium (Na), Iron (Fe) and Manganese (Mn) were measured in total and soluble form. Only one value above detection limits were available for lead and cadmium; this was observed from the GTL analysis.

All other samples were below JCUWD's 100 μg/l detection level for lead and the 500 μg/l or 10 μg/l detection limits for cadmium (depending on which AA instrument was used). The GTL analysis of stream and tributary samples show very low lead concentrations, between 13 and 17 μg/l, and low cadmium concentrations, between 1 and 4 μg/l.

Copper concentrations tended to increase from IS1 to IS5, and the tributaries had lower concentrations than the stream sites. Zinc concentrations also increased from IS1 to IS5; IS2, with the light industrial area, had similar concentrations as the stream stations while IS4 had lower concentrations. Sodium concentrations showed no major differences between stations. Iron and manganese concentrations tended to increase in the downstream, more urbanized stations, and IS2 had concentrations more similar to the stream sites than to IS4. Median concentrations and ranges in μg/l for these metals are presented below:

Parameter	Station	Median	Range	Number < 30 μg/l - Total Samples
Copper (Cu)	IS1	68	20-186	1-8
	IS5	94	11-243	2-6
	IS2	54	25-176	1-6
	IS4	43	11-64	3-8

Parameter	Station	Median	Range	Total Samples
Zinc (Zn)	IS1	320	< 10-865	13
	IS5	478	115-2,770	12
	IS2	430	60-2,330	6
	IS4	189	95-1,180	12
Sodium (Na)	IS1	24,500	11,900-69,599	13
	IS5	26,849	11,800-50,000	12
	IS2	19,399	11,200-27,799	6
	IS4	20,750	1,000-33,099	12
Iron (Fe)	IS1	28,500	177-182,000	13
	IS5	46,650	1,770-121,600	12
	IS2	35,950	690-200,200	6
	IS4	15,300	10,500-35,230	12

Parameter	Station	Median	Range	Sample < 30 µg/l Total Samples
Manganese (Mn)	IS1	1,180	430-6,800	0-13
	IS5	1,340	100-2,682	1-12
	IS2	1,070	< 10-10,000	1-6
	IS4	497	320-1,320	0-12

2.2.3.2 SOLUBLE FRACTION

Kjeldahl nitrogen and phosphorus were measured in both the total and soluble form. In both stream and tributary stations, 35 to 55% of the total Kjeldahl nitrogen was soluble. Phosphorus soluble fractions showed more variability, with the stream stations ranging from 35-65% mean soluble phosphorus and the tributary stations ranging from 15-25% mean soluble phosphorus. Representative soluble fractions of Kjeldahl nitrogen and phosphorus are presented below:

	Mean % Soluble	
Station	TKNT	TPT
IS1	45	48
IS5	45	36
IS2	48	17
IS4	35	25

Copper, zinc, iron and manganese were also measured in both total and soluble form. Copper and zinc varied in percent solubility between stations. Iron and manganese were both at least 85% insoluble.

Wet Weather Metals Solubility
Indian Creek

	Mean % Soluble			
Station	Cu	Zn	Fe	Mn
IS1	58	57	1	10
IS5	30	100	1	9
IS2	49	35	1	13
IS4	76	92	2	11

2.2.3.3 CHEMICAL SPECIES DISTRIBUTION

The distribution of total nitrogen in the form of organic nitrogen, ammonia nitrogen, nitrate and nitrite nitrogen is shown below.

Distribution of Nitrogen in Indian Creek Runoff

	Mean Percent of Total Nitrogen			
	Organic	NH_3	NO_3	NO_2
IS1	57	16	23	3
IS5	40	24	32	3
IS2	58	9	32	1
IS4	50	10	38	3

In Indian Creek stream and tributary stations, 40-60% of the total nitrogen was organic, 10-25% was ammonia, 20-40% was nitrate and nitrite was less than 5% of the total nitrogen. This nitrogen distribution corresponds closely to the Rock Creek stream distributions, the land use site distributions, and with general nitrogen distributions reported in the literature.

Total organic nitrogen tended to decrease from IS1 to IS5 during storms while the nitrate form tended to increase. The nitrification process of conversion of ammonia to nitrate as distance from the treatment plant increased was not seen in storm samples as it was in dry weather samples. The percentage of ammonia increased through the urbanized area, reflecting lower organic nitrogen concentrations in the urban runoff. The percentage of ammonia was higher in the streams than in the tributaries, however, which was probably related to the high base flow ammonia concentrations.

Total phosphorus in Indian Creek was found to be between 35 and 65% soluble in the stream stations compared to 15-25% in the tributary stations. The orthophosphate fraction of the total soluble phosphorus was also variable, ranging from 55 to 90% of the total:

Phosphorus Distribution in Indian Creek Runoff

	Soluble-P/Total-P (%)	Ortho P/Soluble-P (%)
IS1	48	82
IS5	36	90
IS2	17	58
IS4	25	70

Phosphorus/nitrogen ratios were calculated and showed that the stream stations had lower P·N ratios than the tributaries. In general Indian Creek stations had higher ratios than the Rock Creek stations·

Station	P:N Ratio
IS1	1:3
IS5	1:3
IS2	1·4
IS4	1:5

As with Rock Creek, the runoff would create a nitrogen limited condition for any aquatic plant growth, although the ratios are much closer to the 1·7 ratio of nutrient utilization than Rock Creek ratios.

2.2.3.4 FIELD DATA

Dissolved oxygen was measured about 60% of the time during field visits to stations during storms. A summary is presented below for stream and tributary stations·

D.O. (mg/l) IN INDIAN CREEK DURING STORMS

	MEAN	RANGE
IS1	7.7	5.3 - 12.2
IS3	7.9	5.5 - 13.4
IS5	7.5	3.1 - 13.2
IS2	9.0	6.0 - 16.8
IS4	9.0	6.2 - 13.4

Station IS5 had the lowest measured D.O. concentration and the lowest mean of the stream stations. The stream stations as a whole had lower ranges and lower mean concentrations than the tributaries. In the tributaries, D.O. concentrations never fell below 6 mg/l while the stream stations exhibited concentrations below 6 mg/l several times.

Dissolved oxygen was measured during the duration of a runoff event for several storms, and showed that stream D.O. concentrations fluctuated during the duration of an event. Results of these analyses suggest several general trends·

1. Dissolved oxygen concentrations generally fell during the course of an event, but the depression was short lived and concentrations generally returned to pre-storm levels within 24 hours.

2. Station IS5, the most urbanized station, exhibited lower and more prolonged D.O. depressions; station IS1 was often returning to normal levels while concentrations at IS5 were still declining.

3. The duration of the D.O. depression usually corresponded to the duration of the storm.

4. The varying degrees of D.O. fluctuation were probably related to individual storm pollutant loading, storm duration, water temperature and time of day.

Results of several storms in which consecutive D.O. measurements were made are summarized below and in Figure 2.13.

Event	Date	Duration	IS5 Peak Flow (cfs)	IS5 COD Concen. (mg/l)	DO Characteristics
14	9/1/81-9/2/81	22 hours	415	65.3	* IS1 increased .25 mg/l * IS3 decreased .7 mg/l * IS5 decreased 1.3 mg/l * IS1 was beginning to increase while IS5 was still decreasing
16	9/25/81-9/26/81	27 hours	100-120	85.9	* IS3 decreased 1 mg/l * IS5 decreased 2 mg/l * IS1 decreased unknown amount
20	11/1/82	12 hours	784	44.6	* IS1 decreased 0-.6 mg/l then began to rise again * IS3 decreased 0.7 mg/l, then leveled off * IS5 decreased 0.7 mg/l and was still declining when the sampling ended.
34	5/21/82	9 hours	540	116.0	* IS1 increased 1 mg/l * IS3 increased 0.7 mg/l * IS5 increased 0.4 mg/l

Because D.O. measurements were infrequently taken during the characteristically low D.O. nighttime hours, and it is not known how low concentrations fell during this time. However, if they did decline much further than what was measured, it appears that the depression would have been brief since measurements taken during early morning hours following a storm were usually beginning to level off or increase.

IN-STORM DISSOLVED OXYGEN FLUCTUATIONS

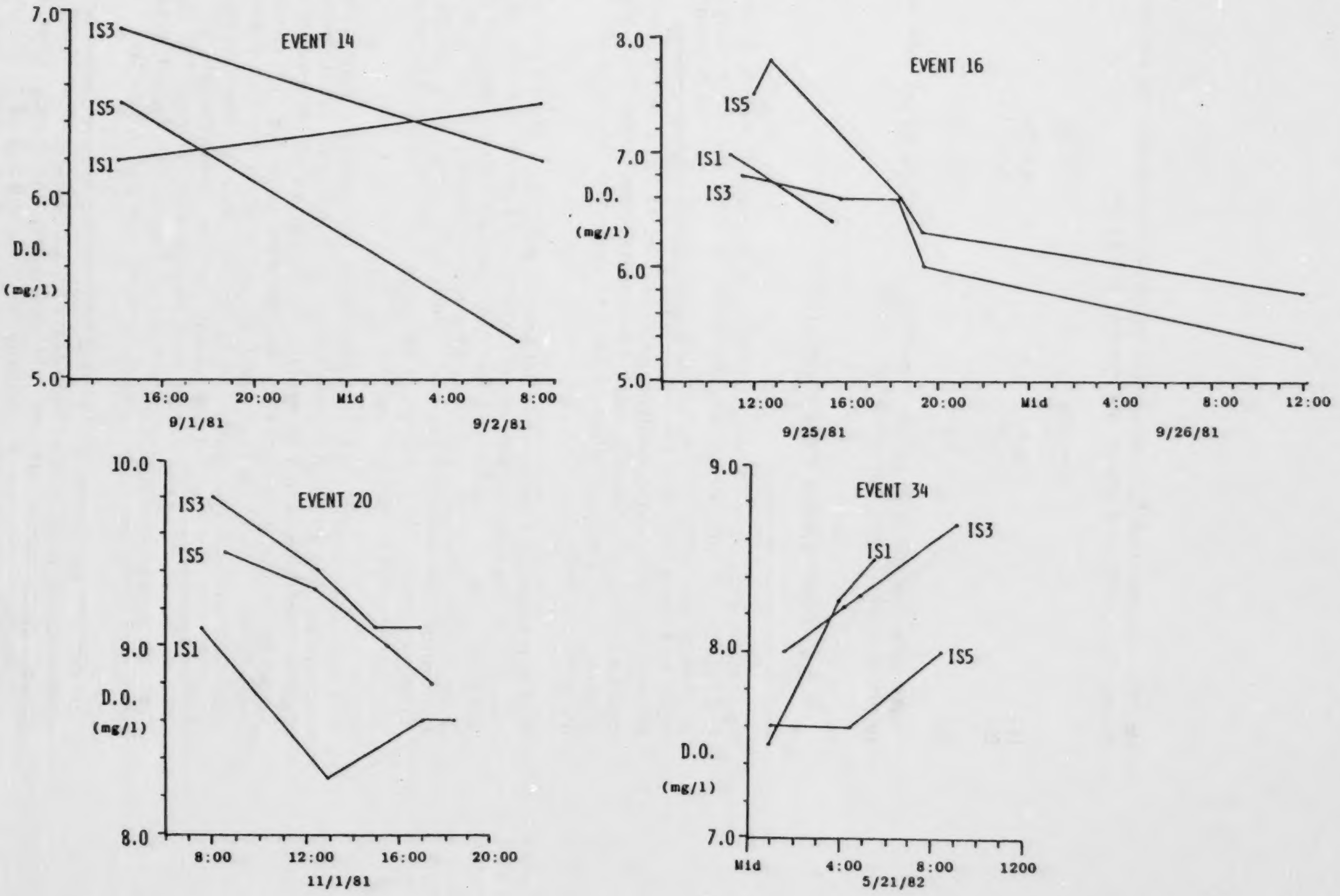

FIGURE 2.13

No COD concentration-D.O. depression trends were observed. pH was also measured during field visits and values are summarized below.

	Average	Range
IS1	6.9	6.4-7.4
IS5	6.9	6.6-7.4
IS4	7.0	6.4-7.6

These data indicate that isolated lowering or elevating of pH does not typically occur in Indian Creek due to urban runoff.

2.3 POST STORM CONCENTRATIONS

Post storm grab samples were analyzed after several events in Indian Creek. This aspect of the study was designed to determine the duration of the concentrations caused by storm events, which is important for determining whether there is a need for separate wet weather water quality criteria. Once it is determined that a water quality constituent occurs in concentrations that violate criteria during storms, any short term acute effect can be evaluated. The duration of an accurate effect is vital to determine the duration of impairment of beneficial uses.

Post storm sampling time varied between 1 and 4 days after a storm event. The most recent dry weather concentration before the storm was used as the baseline condition. The dry weather and post storm samples were collected as instantaneous grab samples while the storm samples represent concentrations from a sample composited over several hours time. Post storm sample concentrations for Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Total Phosphorus (TPT), and Ammonia (NH_3) were evaluated.

TSS and COD concentrations showed a fairly predictable change during and after storms, resulting in elevated concentrations that quickly fell to more typical dry weather conditions within 24 hours. The magnitude of the concentration change varied but consistently increased, and the duration of the high concentration was short. This implies that TSS and COD problems, at least in Indian Creek, are not manifested in the basin itself, but are quickly transported downstream. Problems associated with these elevated storm concentrations will probably be seen in the larger watercourses that receive slugs of high TSS and COD loads from many urban basins. The extent of the problem will depend on the cumulative effects of individual river hydraulics, basin size and hydrology.

The nutrient parameters of TPT and NH_3 seemed to be closely tied to the point source discharge in Indian Creek for all but relatively brief high runoff periods. Stream concentrations of TPT and NH_3 during and shortly after storms varied considerably. While there is a large nonpoint source load contributed by runoff, the background point source load and dry weather settling are probably high enough that they control Indian Creek nutrient concentration factors most of the time.

TSS

Three storm series were available for evaluating the prestorm, in-storm and post storm TSS concentrations: Event 15 in September 1981, Event 50 in August 1982 and Event 55 in September 1982. The resulting concentrations are illustrated in Figure 2.14. There was no baseline dry weather sample available for Event 15, which had 10-20 times higher TSS concentration than average dry weather concentrations. At IS1 and IS5 the post storm grab sample was taken the following day and TSS concentrations were already less than fifty percent of the storm flow concentrations, but still about 2 times as high as normal low flow conditions. The next dry weather sample was taken 2 weeks later, representing baseline conditions. It is not known how much time passed before concentrations stabilized at this level; however the rapid post storm decline indicates that TSS concentrations fall rapidly following runoff events.

Event 50 during August 1982 illustrates a complete dry-storm post storm series for IS1, IS3 and IS5. In this case, the dry weather sample was taken the day before the storm, providing good baseline data to represent average conditions. TSS concentrations rose by a factor of 2000-3000 times over over low flow values during Event 50. The post storm sample was taken 5 days later and by this time TSS had returned to near average dry flow levels.

After Event 55 in September 1982 TSS concentrations rapidly returned to base flow levels. A two hundred fold increase in TSS concentration had fallen to just two times the base flow concentration by the following day at IS3 and slightly more at IS5.

COD

COD concentrations followed a similar pattern where storms resulted in elevated stream concentrations that quickly decreased to dry weather conditions. These patterns are shown in Figure 2.15. Event 15 in September 1981 elevated stream COD concentrations at all stations, which declined to typical dry weather conditions by the following day. The same pattern developed in May 1982 following Event 29.

TPT

TPT dry weather concentrations were closely related to the high treatment plant concentrations at station IP and typically decreased steadily downstream from IS1 to IS5. Instream wet weather TPT concentrations varied greatly and were sometimes lower than dry concentrations because of dilution by runoff with low phosphorus concentrations. Storms with higher TPT concentrations than dry weather data indicate instances of either high nonpoint storm loads or washout of settled TPT downstream of the plant.

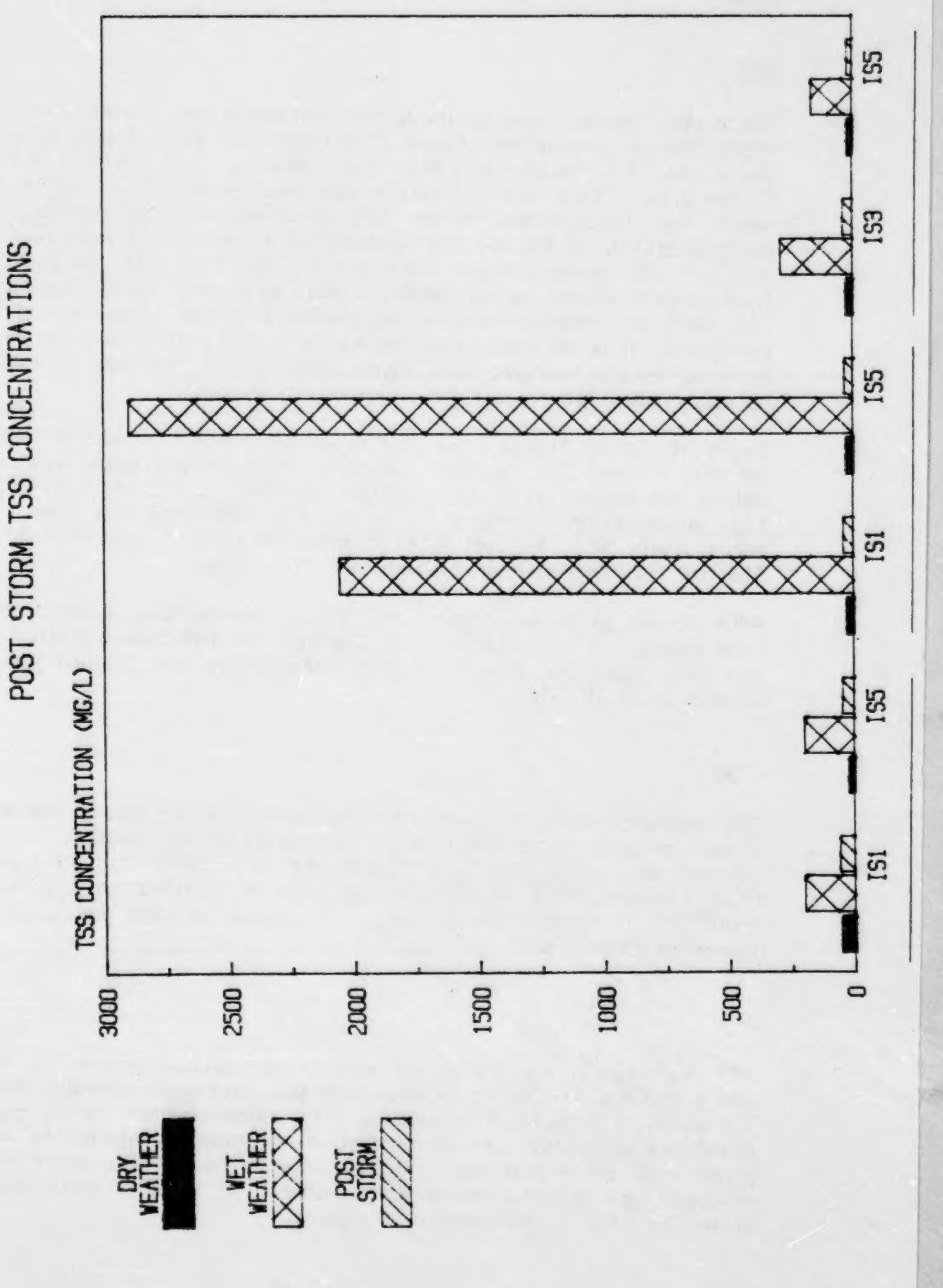
POST STORM TSS CONCENTRATIONS
TSS CONCENTRATION (MG/L)
3000
2500
2000
1500
1000
500
0
IS1
IS5
IS1
IS5
IS3
IS5
DRY WEATHER
WET WEATHER
POST STORM

FIGURE 2.14

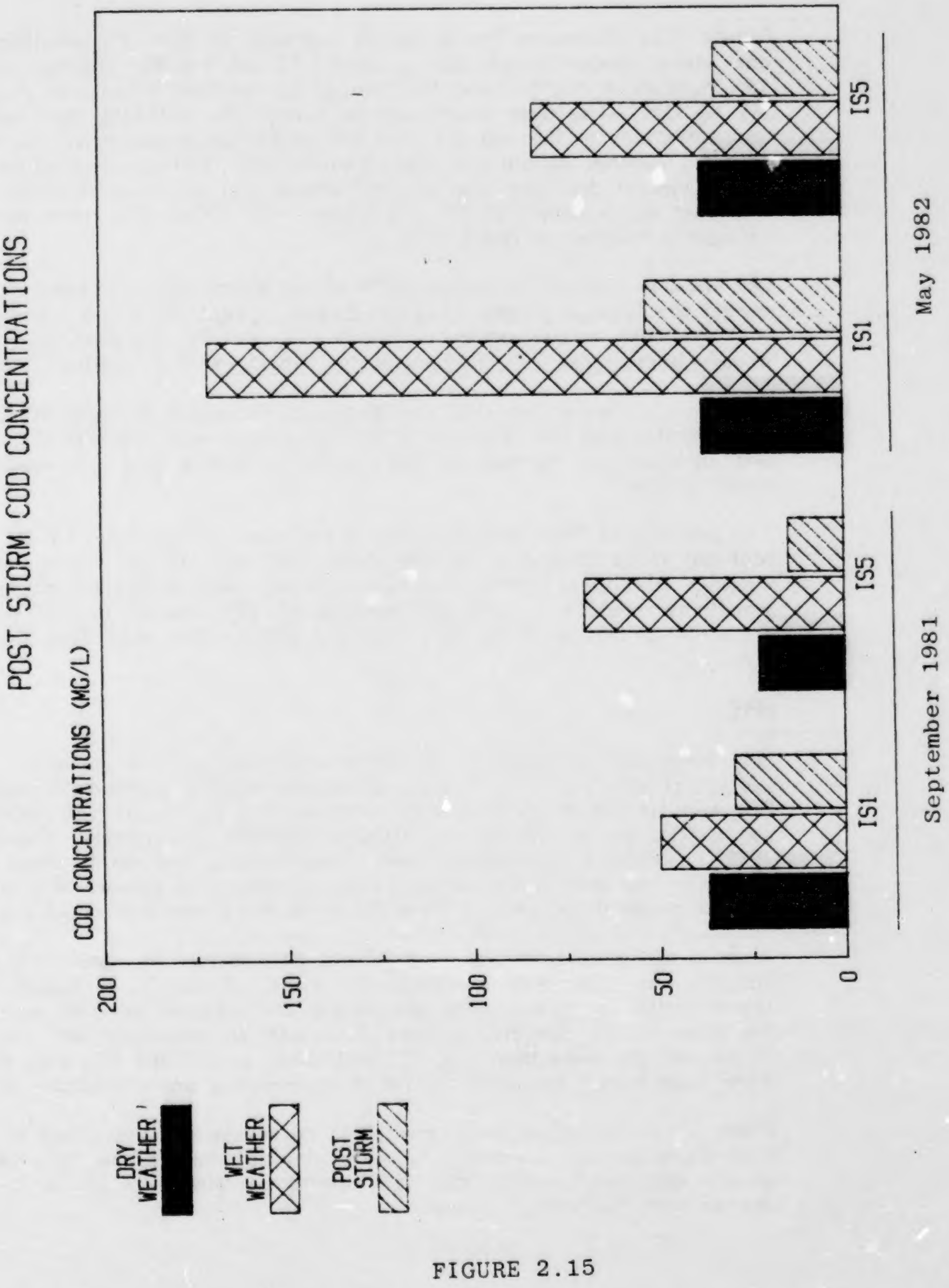
POST STORM COD CONCENTRATIONS
COD CONCENTRATIONS (MG/L)
200
150
100
50
0
IS1
IS5
IS1
IS5
September 1981
May 1982
DRY WEATHER
WET WEATHER
POST STORM

FIGURE 2.15

Figure 2.16 illustrates the different patterns of TPT dry weather, storm, and post storm concentrations during events 15, 29 and 50. During Event 15, storm TPT concentrations followed the typical dry weather pattern of decreasing from IS1 to IS5. The post storm sample taken the following day had lower TPT concentrations at IS1 and IS3 than the storm concentrations. By the time the next dry weather sample was taken 2 weeks later, TPT concentrations had returned to the typical dry flow high concentrations that decrease from IS1 through IS5. The post storm sample at IS5 was higher in TPT than the storm sample, possibly reflecting residual nonpoint load.

Dry weather samples in August 1982 show typical effluent dominated TPT levels during dry flow conditions in Indian Creek. Event 50 during this month resulted in higher than normal concentrations at IS3 and IS5. The post storm sample taken 4 days later shows TPT concentrations typical of dry weather conditions.

Event 55 in September 1982 resulted in lower concentrations at IS3 and higher concentrations at IS5. The post storm sample the next day was already increasing and continued to increase as seen in the next available dry weather sample in early October.

The pattern of TPT response was much more varied than TSS or COD and is probably more dependent on the storm intensity, duration and antecedent dry weather stream concentration. TPT is closely related to point source mechanics, which may include settling and washout of TPT downstream of the plant, and the storm impact seems to vary in extent and duration according to these factors.

NH_3

NH_3 concentration patterns varied greatly during storm periods. Figure 2.17 illustrates some examples of dry weather, storm and post storm NH_3 concentrations. Dry weather concentrations were typically highest at IS1 and decreased to IS5 as nitrification converted the effluent ammonia to nitrate. Event 29 in May 1982 illustrates a case where storm concentrations dropped by about 60% at each station. The post storm sample taken a week later showed NH_3 concentrations to have declined further at IS1 and IS3 and to have remained about the same at IS5.

Another storm several days later (Event 34) resulted in higher NH_3 levels at IS1 and IS3, with IS5 remaining about the same. Event 50 in August 1982 caused the opposite to occur. The preceeding dry weather samples were lower than typically occur, possibly because July was an unusually wet month. Storm concentrations were higher at IS1 and lower at IS3 and IS5; post storm samples were much higher and more typical of dry weather concentrations at all stations.

Event 55 in September 1982 resulted in decreased concentrations at IS3 and IS5. Post storm samples taken the following day had much higher NH_3 values, typical of dry weather; 2 weeks later dry weather samples were similar to the original dry weather September samples.

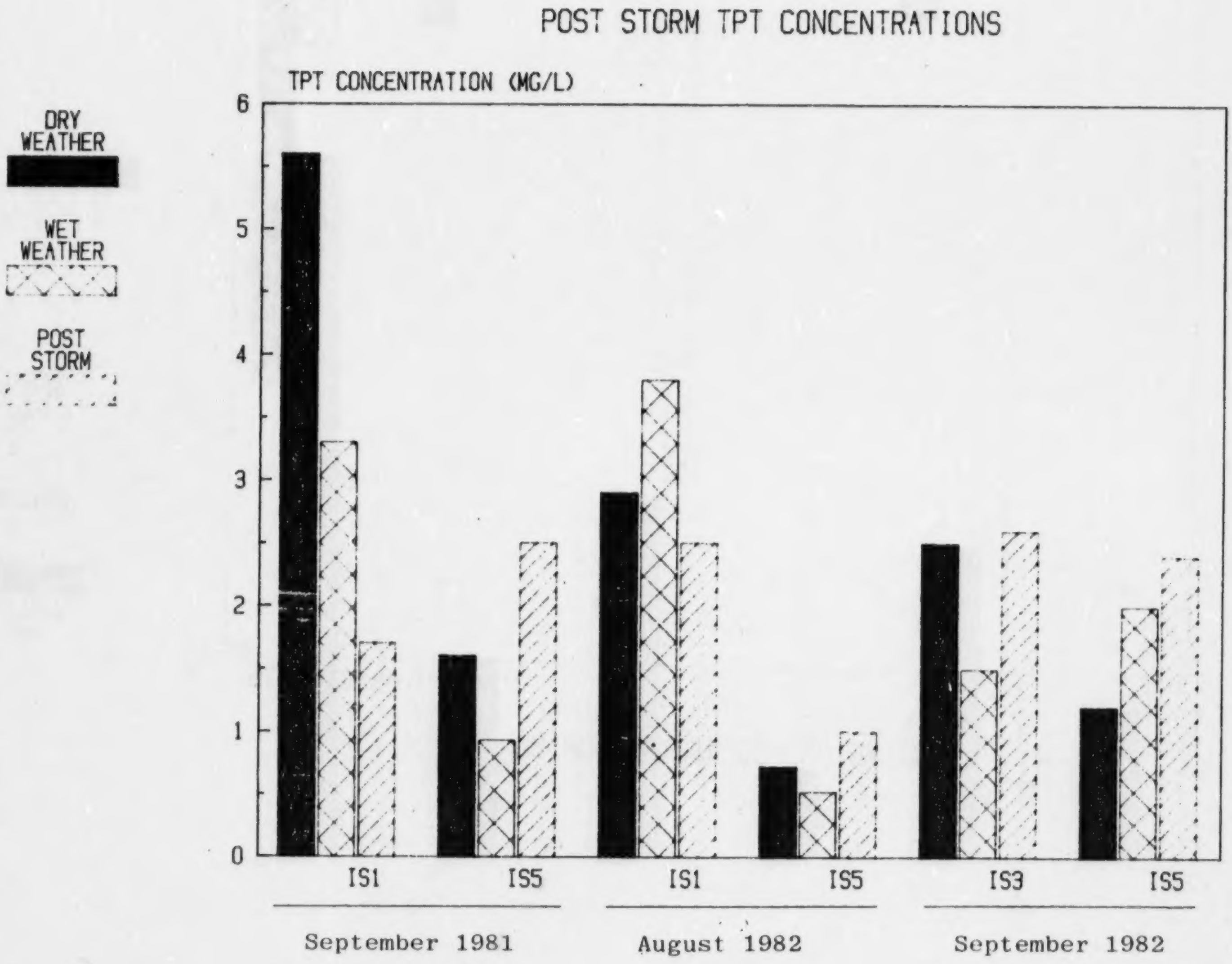
POST STORM TPT CONCENTRATIONS
TPT CONCENTRATION (MG/L)
6
5
4
3
2
1
0
IS1
IS5
IS1
IS5
IS3
IS5
September 1981
August 1982
September 1982
DRY WEATHER
WET WEATHER
POST STORM

FIGURE 2.16

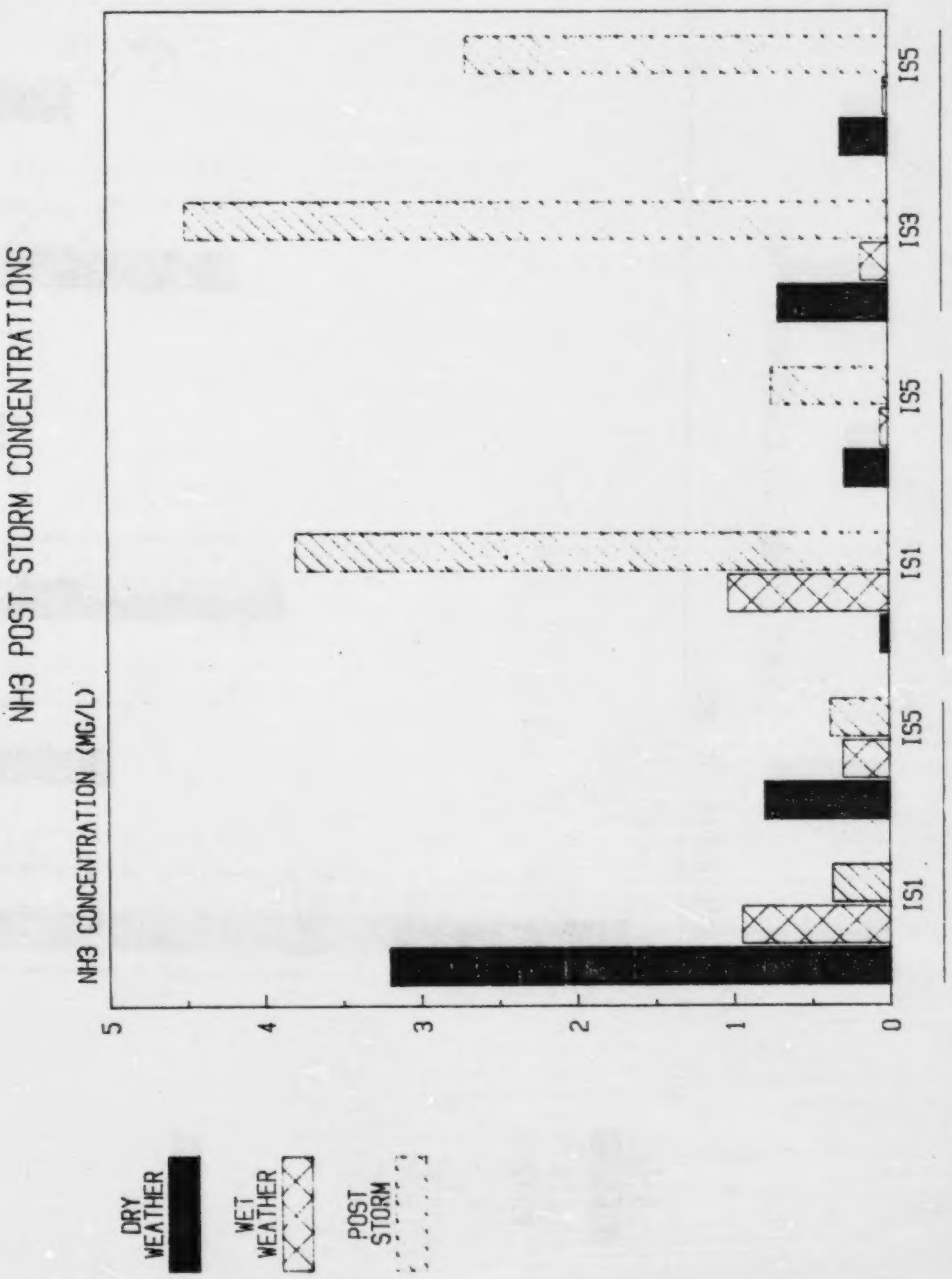
NH3 POST STORM CONCENTRATIONS
NH3 CONCENTRATION (MG/L)
5
4
3
2
1
0
IS1
IS5
IS1
IS5
IS3
IS5
DRY WEATHER
WET WEATHER
POST STORM

FIGURE 2.17

2.4 SPECIAL METALS SURVEY

On May 5, 1982, portions of flow composited samples from eight NURP stations were sent to EPA for a NURP Special Metals Survey. Twenty-nine heavy metals parameters were measured for total, total recoverable, and dissolved concentrations. The results are summarized in Table 2.9.

Although the samples were collected on the same day, the Rock Creek stations (RS1, RS3 and RR) recorded around 1.4" of rain compared to .85" of rain for the Indian Creek stations (IS1, IS3, IS5, IC and II). This may have been responsible for higher Rock Creek pollutant concentrations.

The peak flow rates and runoff volumes at each site are listed below.

Station	Peak Flow (cfs)	Runoff Volume (ft^3)
RS1	--	1.7×10^6
RS3	206	2.3×10^6
RR	1.7	2.2×10^4
IS1	41	1.9×10^6
IS3	72	3.1×10^6
IS5	378	1.0×10^7
IC	15	7.8×10^4
II	15	1.2×10^5

Several elements were not detectable:

Cadmium
Molybdenum
Titanium
Silver

Many of the other elements show Rock Creek concentrations an order of magnitude higher than Indian Creek:

Aluminum
Barium
Chromium
Cobalt
Copper
Iron
Lead
Lithium
Nickel
Vanadium
Yttrium
Zinc

A summary of each parameter follows.

Table 2.9
Special Metals Survey Summary

Parameter	Range (mg/l)	Mean % recov.	Mean% diss.	Notes
Aluminum	1-99	91	<1	Rock Creek higher by order of magnitude
Arsenic	<.01-.11	29	--	RR highest
Boron	<.01-.08	131	160	IS1, RS1 highest
Barium	.03-1.13	103	34	Rock Creek higher by order of magnitude
Berylium	all <.002			
Cadmium	all <.005			None detected
Calcium	24.1-145	105	64	Rock Creek higher
Chromium	<.01-.11	86	0	Rock Creek higher by order of magnitude
Cobalt	<.01-.04	90	0	Rock Creek higher by order of magnitude
Copper	<.02-.12	100	0	Rock Creek higher by order of magnitude
Iron	1.92-97.8	104	<1	Rock Creek higher by order of magnitude
Lead	<.04-.36	89	0	Rock Creek higher by order of magnitude IC four times higher than other Indian Creek
Lithium	<.01-.08	96	0	Rock Creek higher by order of magnitude
Magnesium	1.6-22.1	98	50	Rock Creek higher
Manganese	.07-4.2	109	3	RR highest
Mercury	<.001-.005	--	14	IS5 highest followed by IC (.002 mg/l)
Molybdenum	<.01			None detected
Nickel	<.02-.10	100	0	Rock Creek only detecTable concs.
Potassium	1.4-19.8	94	43	RR highest
Selenium	<.01			None detected
Silver	<.01			None detected
Sodium	4.2-38.0	96	112	IC very low
Strontium	.11-.55	99	69	IC, II lowest
Thallium	<.01			None detected
Tin	<.05			None detected
Titanium	.05-1.83	119	0	IC, II lowest
Vanadium	<.01-.19	95	0	Rock Creek higher by order of magnitude
Yttrium	<.01-.06	93	0	Rock Creek higher by order of magnitude
Zinc	.04-.78	116	8	Rock Creek higher by order of magnitude IC next highest

The two sites with heavy automobile and truck traffic, IC and II, showed high concentrations of lead, mercury and zinc. They had very low concentrations of sodium, strontium and titanium.

All of the metals except arsenic appeared to be greater than 85% recoverable. Measurement near the detection limit caused several values to be greater than 100% recoverable. Only calcium, baron, calcium, magnesium, sodium and strontium averaged more than 50% of the total metal in the dissolved form.

2.5 COMPARISON OF WET WEATHER CONCENTRATION DATA TO DRY WEATHER DATA AND TO STANDARDS AND CRITERIA

Water quality criteria have been established by EPA and adopted by the States to meet the goals of the Clean Water Act. Several criteria are recommended for domestic water supply use. The criteria promolgated by EPA become water quality standards when they are adopted by states as numeric values to be applied to water bodies in the state.

Water quality criteria are "worst case" criteria in that they are concentrations of contaminants in completely available forms that are safe for sensitive organisms for their entire lifetimes or during critical life stages. These criteria are "chronic safe values" and therefore apply more to dry weather concentrations, which stay relatively constant. In contrast, stormwater runoff concentrations may be considered "acute" values; they occur intermittently and for short periods of time. The different nature of runoff borne pollutants limits comparisons against chronic safe value standards to broad generalizations rather than precise definitions of water quality violations.

NURP concentration data from both study area streams were compared to water quality criteria to determine the degree of water quality impairment occurring in receiving waters during both dry and wet flow. Where drinking water criteria are used, they are for comparison only.

The following criteria were evaluated for stations IS1, IS2, IS3, IS4, IS5, RS1, RS2 and RS3.

Parameter	Criteria	Type
Fecal Coliform	2000 cells/100 ml	Standard: Class B waters; State of Kansas
Ammonia	0.15 mg/l	Standard, State of Kansas Freshwater Life
Total Phosphorus	0.10 mg/l	Criteria, EPA, Eutrophication
Nitrate	10.0 mg/l	Criteria, EPA, drinking water
Dissolved Oxygen	5.0 mg/l	Standard, State of Kansas Freshwater Life
Total Cadmium	10 µg/l	Criteria, EPA drinking water
Total Copper	1000 µg/l	Criteria, EPA drinking water
Total Iron	1000 µg/l	Criteria, EPA aquatic life
Total Lead	50 µg/l	Criteria, EPA drinking water
Total Manganese	50 µg/l	Criteria, EPA drinking water
Total Zinc	5000 µg/l	Criteria, EPA drinking water

The land use sites were considered as pollutant generators and were compared against typical point source concentrations. Concentration data from the land use catchments were compared to NPDES general permit levels to determine if concentrations from these sites occur at levels and/or frequencies generally found in wastewater effluent.

The following criteria were evaluated for the land use catchments (IC, II, IR, RC and RR) and are based on general NPDES permit requirements.

TSS	30 mg/l
BOD	30 mg/l
NH_3	5 mg/l
TPT	1.0 mg/l

2.5.1 PERCENTAGE OF SAMPLES EXCEEDING CRITERIA

2.5.1.1 STREAM STATIONS

The ranges, average concentrations, and percent of samples exceeding criteria of the following water quality parameters during dry and wet weather follow.

Ammonia - criteria = 0.15 mg/l

Total ammonia was measured in both laboratories. To convert total ammonia to unionized ammonia, a maximum temperature of 20°C and a maximum pH of 8.0 were used. Any sample with total ammonia concentrations equal to or greater than 4.0 mg/l would contain .15 mg/l unionized ammonia.

No samples exceeded the criteria.

Fecal Coliform - criteria = 2000 cells/100 ml

Station	Dry		Wet	
	Mean* conc. (cells/100 ml)	Samples > criteria (%)	Mean* conc. (cells/100 ml)	Samples > criteria (%)
IS1	< 100	17	5680	60
IS3	< 100	25	7940	92
IS5	< 100	20	18,000	100
IS2			147,435	75
IS4			11,000	82

*geometric mean

Total Phosphorus - criteria = 0.10 mg/l

Station	Dry		Wet	
	Mean conc. (mg/l)	Samples > criteria	Median conc. (mg/l)	Samples > criteria
IS1	3.19	100	2.40	100
IS3	1.97	100	1.10	96
IS5	1.30	100	1.20	100
IS2	0.08	29	0.61	100
IS4	0.16	83	0.42	100
RS1	0.16	80	1.10	100
RS2	0.20	100	0.69	100
RS3	0.19	100	0.77	100

Dissolved Oxygen - criteria = 5.0 mg/l

Station	Dry		Wet	
	Mean conc. (mg/l)	Samples > criteria (%)	Median conc. (mg/l)	Samples > criteria (%)
IS1	9.2	0	7.6	0
IS3	9.2	22	8.0	0
IS5	9.7	0	7.5	9
IS2	11.0	0	8.6	0
IS4	10.9	0	9.1	0
RS1	--	--	8.2	0
RS2	--	--	7.8	0
RS3	--	--	7.4	0

Total Lead - criteria = 50 µg/l

Station	Dry		Wet	
	Mean conc. (µg/l)	Samples > criteria (%)	Median conc. (µg/l)	Samples > criteria (%)
IS1	< 100	0	< 100	0
IS3	< 100	0	< 100	0
IS5	< 100	0	< 100	0
IS2	< 100	0	< 100	0
IS4	< 100	0	< 100	0
RS1	< 100	0	< 100	78
RS2	< 100	0	< 100	100
RS3	< 100	0	< 100	67

Total Iron - criteria = 1000 µg/l

Station	Dry		Wet	
	Mean conc. (µg/l)	Samples > criteria (%)	Median conc. (µg/l)	Samples > criteria (%)
IS1	1186	29	28,500	92
IS3	812	14	13,700	92
IS5	816	14	46,650	100
IS2	614	20	35,950	83
IS4	690	29	15,300	100
RS1	641	17	30,500	81
RS2	541	0	20,145	100
RS3	700	17	39,000	94

Total Manganese - criteria = 50 μg/l

Station	Dry		Wet	
	Mean conc. (μg/l)	Samples < criteria (%)	Median conc. (μg/l)	Samples < criteria (%)
IS1	< 365	100	1180	100
IS3	< 310	100	360	100
IS5	< 257	100	1340	100
IS2	< 202	100	1070	83
IS4	< 152	100	497	100
RS1	234	100	1110	100
RS2	282	100	1214	89
RS3	450	100	870	100

Table 2.10 summarizes when concentrations were higher in dry vs. wet weather, and which flow regime had the greater percentage of samples exceeding criteria.

Table 2.10
Standards Criteria Exceedence and Average Concentrations in Dry vs. Wet Weather

	Station	Flow regime with higher average concentration	Flow regime with more frequent exceedence of criteria
Fecal Coliform	IS1	W	W
	IS3	W	W
	IS5	W	W
Total Phosphorus	IS1	D	E
	IS3	D	E
	IS5	D	E
	IS2	W	W
	IS4	W	W
	RS1	W	W
	RS2	W	E
	RS3	W	E
Nitrate	IS1	D	E
	IS3	D	E
	IS5	D	E
	IS2	D	E
	IS4	D	E
	RS1	W	E
	RS2	W	E
	RS3	D	E
Dissolved Oxygen	IS1	D	E
	IS3	D	D
	IS5	D	W
	IS2	D	E
	IS4	D	E

Cadmium	all below detection limits		
Copper	all below detection limits		
Iron	IS1	W	W
	IS3	W	W
	IS5	W	W
	IS2	W	W
	IS4	W	W
	RS1	W	W
	RS2	W	W
	RS3	W	W
Lead	IS1	E	E
	IS3	E	E
	IS5	E	E
	IS2	E	E
	IS4	E	E
	RS1	E	W
	RS2	E	W
	RS3	E	W
Zinc	IS1	D	E
	IS3	D	E
	IS5	D	E
	IS2	D	E
	IS4	D	E
	RS1	D	E
	RS2	D	E
	RS3	D	E
Manganese	IS1	W	E
	IS3	W	E
	IS5	W	E
	IS2	W	E
	IS4	W	E
	RS1	W	E
	RS2	W	E
	RS3	W	E

2.5.1.2 LAND USE STATIONS

Comparisons against general NPDES standards for the land use stations are presented below.

TSS

	Median (mg/l)	% samples > 30 mg/l
IC	34	56
II	59	82
IR	100	100
RC	197	100
RR	1787	100

BOD

	Median (mg/l)	% samples > 30 mg/l
IC	7	7
II	10	12
IR	19	20
RC	17	30
RR	13	0

TPT

	Median (mg/l)	% samples > 1.0 mg/l
IC	0.17	4
II	0.32	10
IR	0.58	33
RC	0.46	0
RR	1.7	78

Ammonia - no values over 5 mg/l

2.5.2 IMPACT ON BENEFICIAL USES

Fecal Coliform

Urban runoff produced high coliform counts in Indian Creek. Fecal coliform concentrations increased by a factor of three from station IS1 to the more urbanized IS5 station during storm events. The geometric mean of < 100/200 ml during dry weather at IS5 rose to 18,000/200 ml during wet weather. The standard of 2000 cells/100 ml was exceeded 60-100 percent of the time during wet weather and less than 25% of the time during dry weather. It is not known how long the elevated fecal coliform levels persisted; since Indian Creek itself is rarely used for whole body contact, the concentrations probably do not present a severe problem in the creek. However, the high coliform concentrations suggest that recreational lakes draining similar watersheds can be contaminated by urban runoff.

Total Phosphorus

The criteria of 0.10 mg/l total phosphorus is recommended by EPA for streams not discharging directly to a lake or impoundment in order to prevent plant nuisances within the stream. Average dry weather phosphorus concentrations in Rock Creek were approximately two times this level; wet weather concentrations were considerably higher and varied from 1.7 to 10 times the dry weather levels. While dry weather concentrations typically exceed the 0.10 mg/l criteria, urban runoff results in concentrations that not only exceed the criteria, but also result in phosphorus levels high enough to pose plant nuisance problems in area impoundments.

Median dry and wet weather concentrations in Indian Creek tributaries are slightly lower than in Rock Creek; however the same potential problem was evident.

In Indian Creek stream stations, total phosphorus concentrations are more influenced by the point source. Although storm concentrations are generally lower than dry weather concentrations, the 0.10 mg/l criteria is exceeded in the creek essentially 100% of the time during both flow regimes. These data indicate that urban runoff related phosphorus concentrations in both study areas are high enough to pose potential problems for a downstream impoundment. Generally, at least 50% of the phosphorus was soluble, and of this, about 90% was in the available orthophosphate form during wet weather.

Nitrate

The 10 mg/l nitrate standard is used for drinking water, and neither dry nor wet weather concentrations result in levels high enough to pose problems if these streams were used for public water supply.

Dissolved Oxygen

Urban runoff was seen to cause brief periods of D.O. depressions in Indian Creek, but it appears that neither stream has a prolonged problem with lowering of dissolved oxygen levels during storms.

Total Cadmium

Every station had average cadmium concentrations of less than 10 µg/l which is the EPA criteria for drinking water. Neither dry nor storm concentrations exceeded this level in any sample.

Iron

Iron concentrations increased dramatically during storms as compared to dry weather levels in both study areas and at all stations. Overall, less than 30% of dry weather samples had concentrations exceeding the criteria, compared to more than 80% of the urban runoff samples. This indicates urban runoff in these basins contributes significantly to instream iron concentrations. Both basins had increased average concentrations proceeding downstream; IS2, which drains the industrial park was higher overall than IS4, which drains primarily a residential area. Since most of the iron was attached to sediment, accumulations in the settled bottom sediment may result in aquatic toxicity.

Lead

Lead concentrations were below or near detection limits for all samples in both flow regimes in Indian Creek. In Rock Creek, wet weather concentrations violated the criteria 65-100% of the time, while no violations occurred during dry weather. The higher lead concentrations in Rock Creek may be partially caused by the higher urban density; another cause may be discharges from small metal plating companies in the basin.

Manganese

The standard was violated almost 100% of the time during both dry and wet weather in both creeks and average concentrations were two to five times higher during wet weather in both areas.

2.5.3 COMPARISON TO NPDES REQUIREMENTS

TSS

All land use catchments had at least 50% of the samples with TSS concentrations in excess of the 30 mg/l permit comparison level, and all median concentrations were higher than 30 mg/l. IR, RC and RR exceeded this concentration 100% of the time, II exceeded it 82% of the time, and IC, the paved parking lot and mall, had TSS concentrations higher than 30 mg/l 56% of the time. In general, these data indicate that residential land use is most likely to contribute large amounts of TSS, and that areas with a higher percentage of impervious surfaces are less likely to exceed the guidelines. Even catchments with very little erosion show high TSS levels, probably produced from atmospheric deposition and the deterioration of paved surfaces.

BOD

BOD concentrations from the land use sites were much lower and no station had concentrations in excess of 30 mg/l more than 30% of the time. All median concentrations were below 30 mg/l; thus it appears that BOD concentrations from these land uses were usually below the NPDES effluent comparison.

Total Phosphorus

RR was the only site with a median concentration higher than the 1.0 mg/l effluent comparison, and also exceeded that concentration most often (78% of the samples). Both commercial sites and the light industrial site had less than 10% of the samples in excess of this concentration, and 33% of the samples at IR exceeded 1.0 mg/l.

Because the sites that exceeded the 1.0 mg/l guideline most often were those with the highest percentage of grassy area (RR, IR), the phosphorus problem is likely related to fertilizer application and erosion.

3.0 POLLUTANT LOADING ANALYSIS

Both pollutant concentration and pollutant mass loadings are important in the evaluation of urban runoff impacts. Runoff and receiving water concentrations are usually compared against water quality standards or criteria based on beneficial uses or the survival and propagation of aquatic biota. This type of comparison is limited to a few pollutants because many do not have widely accepted criteria or standards. Pollutant mass loadings are probably more useful than concentrations because they identify source areas and they are a much better predictor of receiving water impacts. The receiving water column concentrations during storm events are a function of runoff loads, and longer term impacts are often related to the settling of runoff loads. Mass balances used to evaluate these processes depend on accurate loading calculations rather than on analysis of concentration data. For these reasons, pollutant mass loads can have a greater importance than concentrations for purposes of management and planning.

Pollutant mass loads can be classified as either wet weather or dry weather (background) loads. Background mass loading is a measure of the amount of a particular pollutant which is transported during periods of dry weather. These loads are expressed as mass per time. Wet weather loading is a measure of the amount of pollutant which is transported during high flows of stormwater runoff. The data is initially expressed as a mass load for each event; this data is then converted to an annual load representing a complete year of runoff.

These two types of loads will be discussed separately, although there is not a clear definitive break between periods of low flow and periods of runoff. For the NURP loading calculations the separation of these periods was based on several years of USGS runoff data as described in chapter one. A second factor which clouds the distinction between dry and wet weather loads is the sedimentation process. During periods of low flow, a portion of the dry weather pollutant load may be deposited on the stream bottom. These deposits can be picked up during periods of higher flows caused by stormwater runoff and thus contribute to the measured wet weather load. Wet weather loads can also accumulate and have an impact on stream water quality during dry periods.

The loading analysis performed on the NURP data compared dry weather and wet weather loadings, and detailed the sources and factors affecting the more complicated wet weather loads. The analysis of the nonpoint data utilized annual loads per acre of different watersheds, and examined the significant differences between NURP stations. The factors behind these differences are examined in Chapter 4.

3.1 DRY WEATHER LOADINGS

3.1.1 ROCK CREEK BACKGROUND LOADS

3.1.1.1 LOW FLOW DISCHARGE

The hydrological analysis discussed in Section 1.4.2.4, "Runoff Volume Based Method", was used to estimate an average base flow values at the location of the USGS gage, Station RS1. An average base flow value of 1.0 cfs was estimated from seven years of hydrologic data. This value was used with mean pollutant concentrations to calculate annual dry weather loads from Rock Creek.

Actual Flow Data

The Rock Creek dry weather flow data was not used because only four sets of flows were available from the five sampling runs (one run was done in winter when the stations shut down). Also, the changing low flow stage-discharge relations at RS2 and RS3 introduced an additional element of error. The average of the RS1 flowrates during the four sampled runs was .6 cfs compared to the computed hydrologic low flow value of 1.0 cfs. These values are close to the limits of accurate measurement at this station. The companion hydrologic low flow values at RS2 and RS3 were calculated by multiplying the RS1 value of 1.0 cfs by the ratios of the RS1-RS2 and RS1-RS3 basin areas. These values were 1.5 cfs for RS2 and 1.75 cfs for RS3.

3.1.1.2 BACKGROUND LOADING RATES

The annual loading rates for low flow or "background" loads were calculated by multiplying the low flow discharge by the mean low flow concentration. Annual background loads were based on 365 days per year of background pollutant transport. The conversion used was: mg/l · cfs · 1,969 = lb/yr . Table 3.1 shows the calculated annual loads (normalized with respect to basin area) in lbs/acre/yr for stations RS1 and RS3.

Table 3.1
Rock Creek Background Loads
lbs/acre/yr

	RS1	RS3
TSS	9.9	9.1
TPT	0.11	0.12
TOTN	0.80	1.06
COD	11.9	11.1
BOD	1.7	1.75
Base Flow (cfs)	1.0	1.75

3.1.2 INDIAN CREEK BACKGROUND LOADS

3.1.2.1 LOW FLOW DISCHARGE

The hydrological analysis discussed in the Rock Creek background loads (Section 3.1.1) was used to estimate average base flow values for the main channel stations IS1, IS3, and IS5. Station IS3 was the location of the USGS gage; flows at IS1 and IS5 were adjusted using ratios of flows from NURP stream flow records. The ratio of IS1 to IS3 flows was .75, and the ratio of IS5 to IS3 flows was 1.30.

The long term hydrologic average base flow values for IS1, IS3, and IS5 were close to the average of the actual flowrates during seven sampling runs.[1]

Average Low Flow Discharge (cfs)

	IS1	IS3	IS5
Estimate from Hydrologic Analysis	5.6	7.5	9.8
Means of Flow During Actual Sample Runs[1]	6.3	8.4	10.9

This suggested the sampling runs were representative of average low flow estimated from long term USGS data.

Actual low flows for Station IP were obtained from selected daily discharge records from the Blackbob treatment plant. Annual low flows for Stations IS2 and IS4 were estimated from the NURP monitoring and gaging data. Low flow at these two sites were estimates because of the extremely low flows and the changing stage discharge curves.

3.1.2.2 BACKGROUND LOADING RATES

Two types of background loads at the Indian Creek Stream Stations were calculated: Low flow loads and point source loads. Low flow background loads at each station were calculated by averaging the product of instantaneous flows and pollutant concentrations and converting to lbs/acre/year and lbs/year. The long-term flow estimates were not used as in Rock Creek calculations because of the larger number of low flow sampling runs, the greater low flow recording accuracy, and for the ease of data analysis. A comparison of the long term hydrologic estimates and the flow values during sampling suggest little difference would have resulted from the use of the hydrologic estimates.

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[1] No flow data was collected from sampling runs 605 and 606 because of station shutdown due to winter season.

Table 3.2
Indian Creek Background Loads
lb/acre/yr

	IS1	IS3	IS5	IS2	IS4
Basin Size Acres	11,005	16,862	23,941	3621	1372
TSS					
Low Flow	33	21[1]	17	4.6[1]	10
TP					
Low Flow	4.0[1]	2.1[1]	1.3	0.02[1]	.10[1]
TOTN					
Low Flow	14	8.0	7.0	.8[1]	1.9
COD					
Low Flow	57	39	29	10.5[1]	18.9
BOD					
Low Flow	14[1]	7.1	5.3	1.8	2.9

[1] Standard Deviation/mean > 66%

Dry weather point source loadings were calculated to compare directly with low flow stream transport independent of rain and infiltration related treatment plant loads. Dry weather point source loads were calculated by averaging the product of pollutant concentration by the flow reported on the day of the sampling. The average flow from these days was 3.2 cfs (2.1 mgd). This data may underrepresent the flow from the plant during dry weather; an average of one mean daily flow from one dry period a month between June, 1981 and July, 1982 showed an average dry weather discharge of 3.9 cfs (2.5 mgd).

Comparison of point source loads and background pollutant loads being transported past IS1, IS3, and IS5 indicates phosphorus settling out downstream of the treatment plant outfall. Roughly 30% of the 170 pounds of phosphorus discharged by the plant on an average day appears to settle out between the plant and IS1 (College Blvd.) during dry weather. An additional 15% seems to settle out in the 3.7 miles between IS1 and IS3 and roughly 6% more between IS3 and IS5 (Mission Rd.). This phosphorus is probably scoured away during storm periods and represents a "pseudo" nonpoint load. An approximate adjustment factor was employed to clear the nonpoint source of this confounding factor.

Almost all of the COD and BOD loads could be attributed to the treatment plant. Some oxidation or deposition of the BOD load was visible in the averaged data, as average IS3 and IS5 in-stream loads were lower than the averaged plant BOD load. Table 3.3 shows the ratios of annual dry weather point source loads to annual background instream loads.

Table 3.3
Ratio of Annual Point Source Loads
to Annual Background Instream Loads (%)

	IS1	IS3	IS5
Stream miles from point source	5.1	8.8	11.7
TSS	34	34	31
TP	141	177	200
TOTN	61	70	57
COD	93	89	85
BOD	94	81	85

Only 50-70% of the total nitrogen and 30-40% of the suspended solids data appeared to be related to the municipal effluent. Most of these loads not associated directly with the plant appeared to come from upstream of IS1, indicating a possible undercalculation of the point source loads or high dry weather agricultural impacts. Although the three main channel stations had very high loads compared to the two tributary stations, the loads from the urban area between IS1 and IS5 appeared to be similar to the tributary loadings. The loads from the urban area were calculated by subtracting IS1 loads from IS5 loads.

3.2 WET WEATHER LOADING CALCULATIONS

3.2.1 INTRODUCTION

A pollutant mass loading is a measure of the amount of a particular pollutant which passes a given station during a specified time period. For purposes of this study, wet weather loads were calculated on the basis of individual storm events. This calculation involved multiplying the event mean concentration (EMC) by the total volume of flow during the event (in ft^3) at that station and applying an appropriate conversion factor to derive the calculated event load in units of pounds.

The loading calculation is sensitive to both the pollutant concentration, and to the total volume of flow. Stations with higher total flow volumes would also be expected to experience higher loads. However, the relationship between loads and flow volume is not linear. Increased flows do not necessarily result in proportionately increased loads because concentrations at these higher flows are often lower due to factors such as dilution.

Average total flow volumes are summarized in Table 3.4 for six selected sites. These sites serve as an illustration of the variation in total flow volumes within and between stations. IS5 and RS3 are the largest major stream sites in Johnson County and Independence, respectively. IS4 is a relatively small tributary to Indian Creek draining areas which are primarily residential and commercial. The remaining three sites RR, IC, and II are small land-use sites draining less than 100 acres each of residential, commercial, and industrial area.

Table 3.4
Average Total Flow Volumes Per Event (ft^3)

	IS5	RS3	IS4	RR	IC	II
mean	1.8×10^7	4.5×10^6	8.6×10^5	2.3×10^4	9.2×10^4	1.1×10^5
min.	6.3×10^5	2.5×10^5	8.9×10^4	3.5×10^2	8.0×10^3	1.8×10^4
max.	8.6×10^7	2.9×10^7	4.1×10^6	9.8×10^4	3.2×10^5	3.4×10^5

As Table 3.4 shows, total flow volumes were highly variable for each station and between stations. This contributed to the high variability of the measured pollutant loads. The arithmetic means and ranges of four selected parameters for these stations are shown in Table 3.5. Ranges are expressed as percent of mean. Event loading data for all sites and all parameters are presented in the appendix.

Table 3.5
Average Pollutant Loads Per Event

	IS5	RS3	IS4	RR	IC	II
TSS						
Mean (lbs)	620,000	440,000	25,000	4,800	500	890
Range (% of Mean)	7-403	1-568	3-348	1-688	1-840	3-494
TPT as P						
Mean (lbs)	1,200	230	35	7.4	1.4	3.3
Range (% of Mean)	1-375	3-522	5-629	1-568	7-629	15-455
Total N						
Mean (lbs)	5,400	307	201		12	13
Range (% of Mean)	4-352	42-263	5-647		3-292	4-300
COD						
Mean (lbs)	106,000	35,000	3,900	530	260	380
Range (% of Mean)	2-642	2-429	10-513	2-849	16-354	26-447

Loadings for the various parameters displayed a great deal of variation between stations, due to a large extent to the difference in measured flowrates. For example, measured TSS loads ranged from over 2.5 million pounds occurring at IS5 following a 1.4 inch rainstorm to 2.2 pounds occurring at IR following a 0.2 inch rain event.

Each station also displayed a wide range in loading values due to variability in storm characteristics, antecedent conditions, watershed characteristics, and other factors. The land use sites generally displayed wider ranges in loads than the stream sites. IC was the most variable of the land use stations, with a coefficient of variation for TSS loadings of over 186 percent. RR was the next most variable site, followed by II. As expected, the most consistent loadings were measured at station IP (point source discharge) which had a coefficient of variation for TSS loadings of less than 60 percent. Station IS2 was the next most consistent site with a coefficient of variation for TSS loadings of approximately 80 percent. Variability of the TSS loadings at the stream sites ranged from 100 to 150 percent, with RS3 showing the most variability, and IS1 displaying the least.

Pollutant loads are much higher at the major stream sites than the smaller land-use sites. This is primarily due to higher runoff volumes from much larger basins. In general, stations with the largest drainage areas and the largest flow volumes had the highest loadings. Total mass loads increased from station IS1 to station IS5. Figure 3.1 illustrates the increase in TSS loads associated with the increase in drainage area for the three major Indian Creek stream stations. This figure

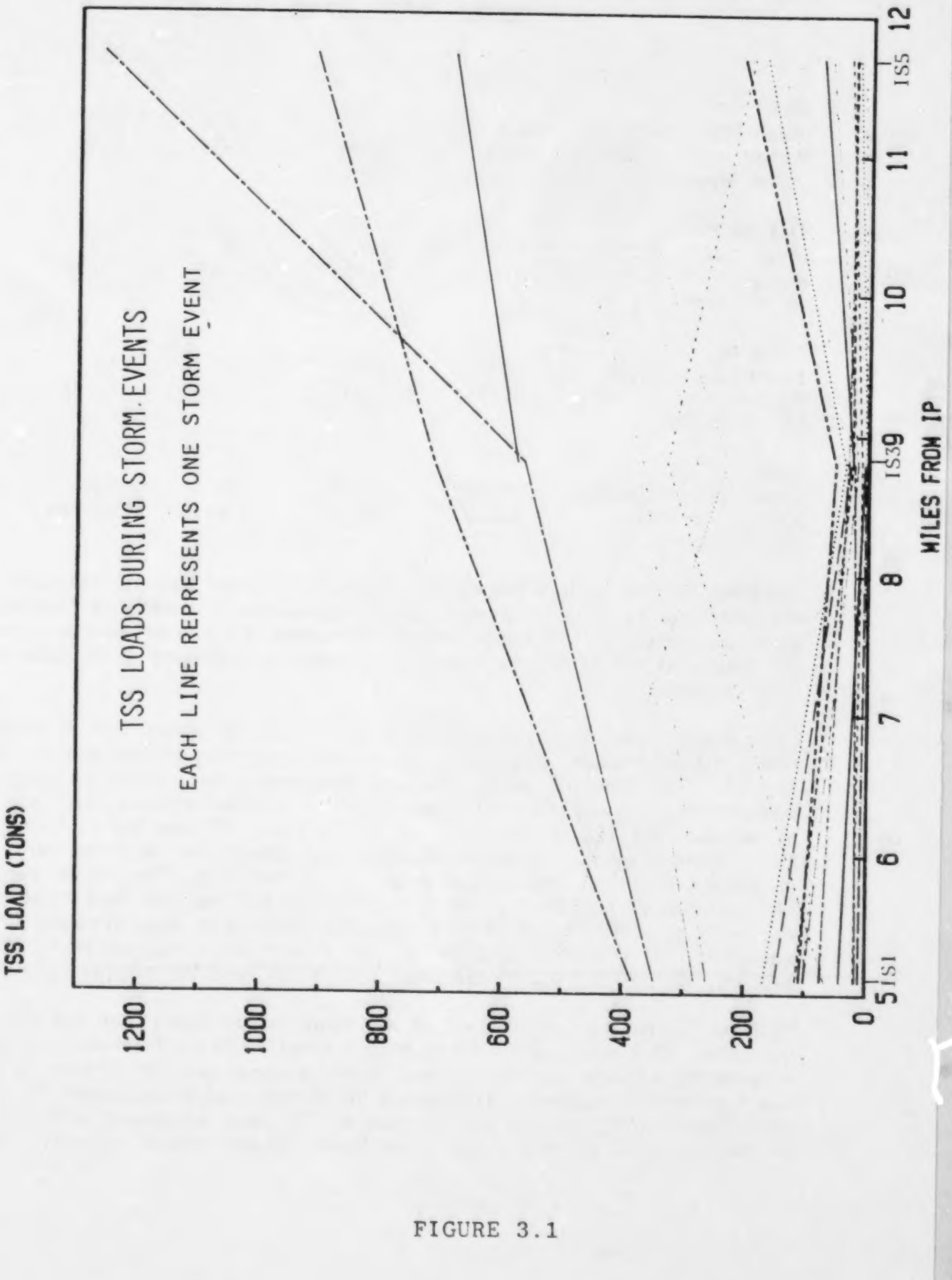

TSS LOADS DURING STORM EVENTS
EACH LINE REPRESENTS ONE STORM EVENT
TSS LOAD (TONS)
1200
1000
800
600
400
200
0
MILES FROM IP
5
6
7
8
9
10
11
12
IS1
IS39
IS5

FIGURE 3.1

shows that one large event can contribute a sediment load many times greater than a number of small events.

A slight depression was observed in TSS loads at station IS3 for the smaller events. During several inspections of Indian Creek, a significant amount of deposition was observed in the reach above station IS3. Sedimentation or monitoring difficulties could possibly have contributed to this depression.

Total nitrogen, total phosphorus, and COD loads increased from stations IS1 to IS5 (Figures 3.2, 3.3 and 3.4). The depression observed at station IS3 for TSS was reflected for these parameters. This could be expected since all these parameters are associated to some extent with the sediment load.

Loading data reported in pounds per event is of limited value for purposes of comparison between stations because of the influence of the total flow volume and because the same events are not sampled at each station. In order to compare stations on an equal basis, loads were first normalized to account for watershed area. This was achieved by dividing by the number of acres in the watershed to give normalized loads in units of pounds per acre. Average normalized event loads for the selected stations and parameters are presented in Table 3.6. Normalized loading data for all stations and parameters are included in the following sections and in the appendix.

Table 3.6
Average Normalized Event Loads (lb/acre/event)

Station	IS5	RS3	IS4	RR	IC	II
Drainage Area (acres)	23,941	5,566	1,372	58	58	72
TSS	26	79	18	83	8.6	12
TP_{TOTAL}	.05	.04	.03	.13	.02	.05
Total N	.23	.05	.15		.21	.18
COD	4.4	6.3	2.8	9.1	4.5	5.3

Normalized loadings can be used to compare the loads generated at different stations for a series of storms, or for a particular storm. Figure 3.5 compares normalized sediment (TSS) loads at the Independence commercial site (RC) with the Independence residential site (RR) for several events. The watershed above station RR clearly contributes much greater amounts of sediment per acre than station RC. Figure 3.6 compares normalized sediment loads at two major stream sites, stations RS1 and RS3. Loadings at these two stations are similar when the influence of the drainage area is eliminated. Slightly higher normalized sediment loadings were measured at station RS1 for smaller events, and normalized

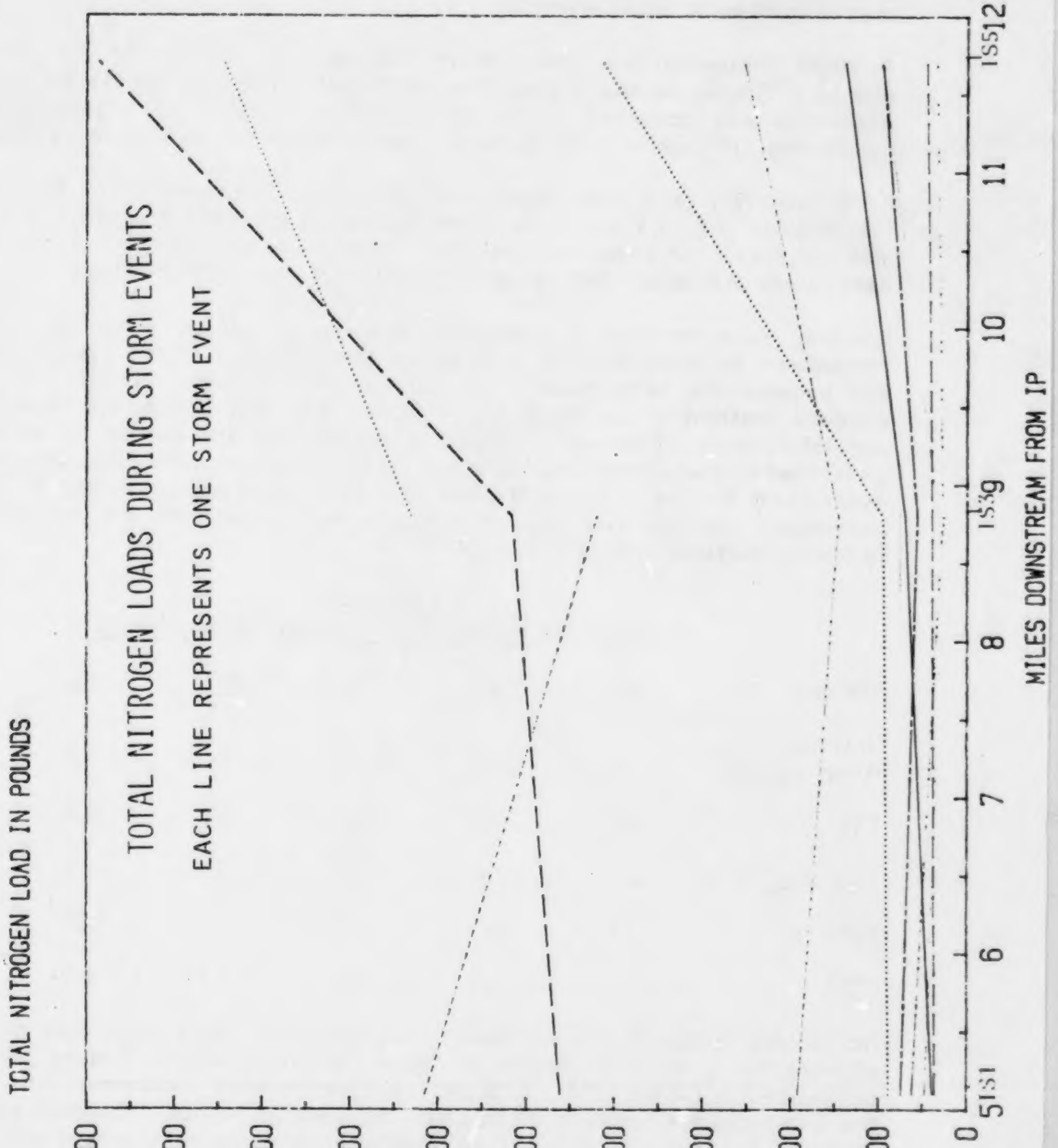

TOTAL NITROGEN LOADS DURING STORM EVENTS
EACH LINE REPRESENTS ONE STORM EVENT
TOTAL NITROGEN LOAD IN POUNDS
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
MILES DOWNSTREAM FROM IP
5
6
7
8
9
10
11
12
IS1
IS3
IS5

FIGURE 3.2

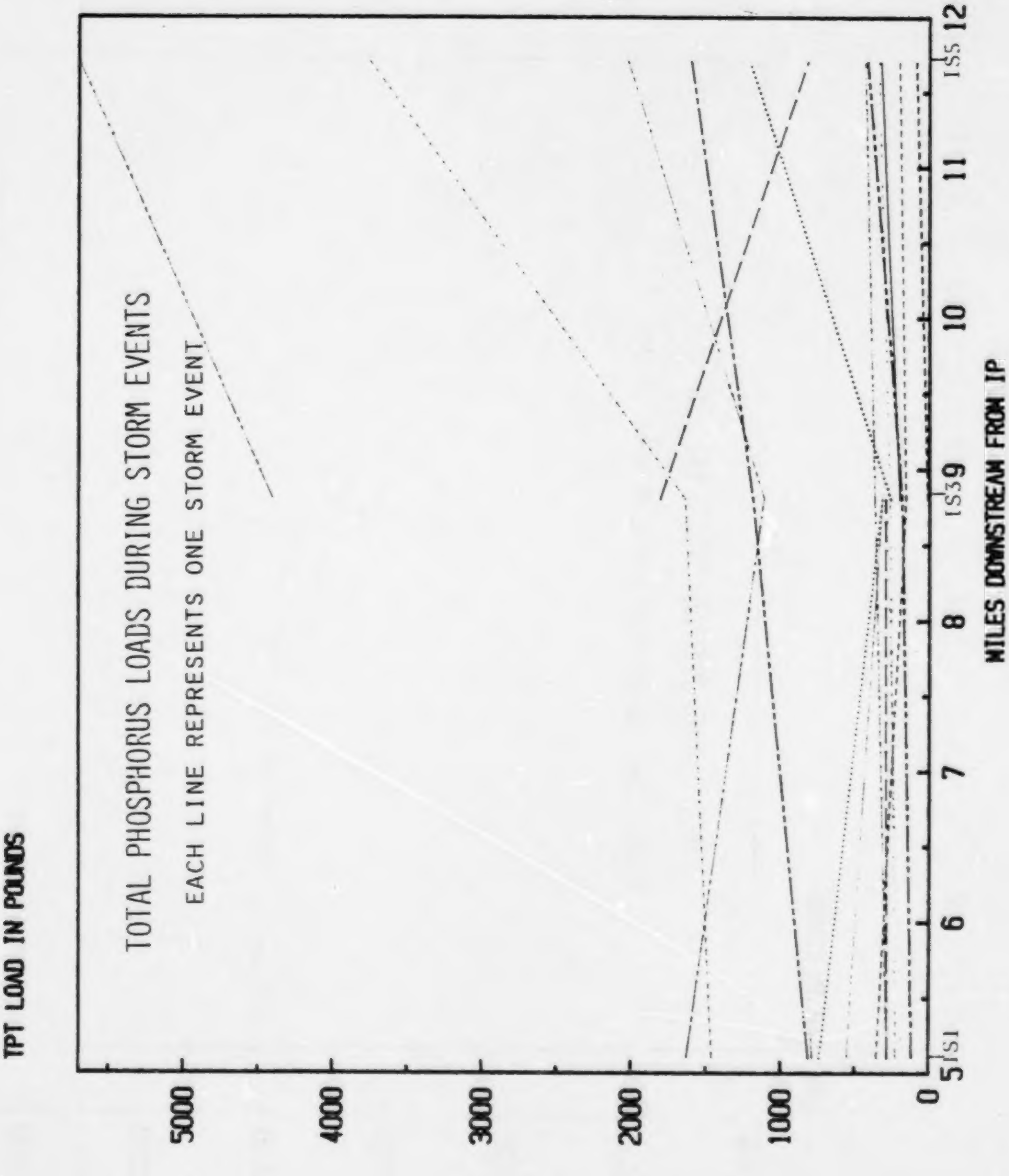

TPT LOAD IN POUNDS
TOTAL PHOSPHORUS LOADS DURING STORM EVENTS
EACH LINE REPRESENTS ONE STORM EVENT
0
1000
2000
3000
4000
5000
5
6
7
8
9
10
11
12
IS1
IS3
IS5
MILES DOWNSTREAM FROM IP

FIGURE 3.3

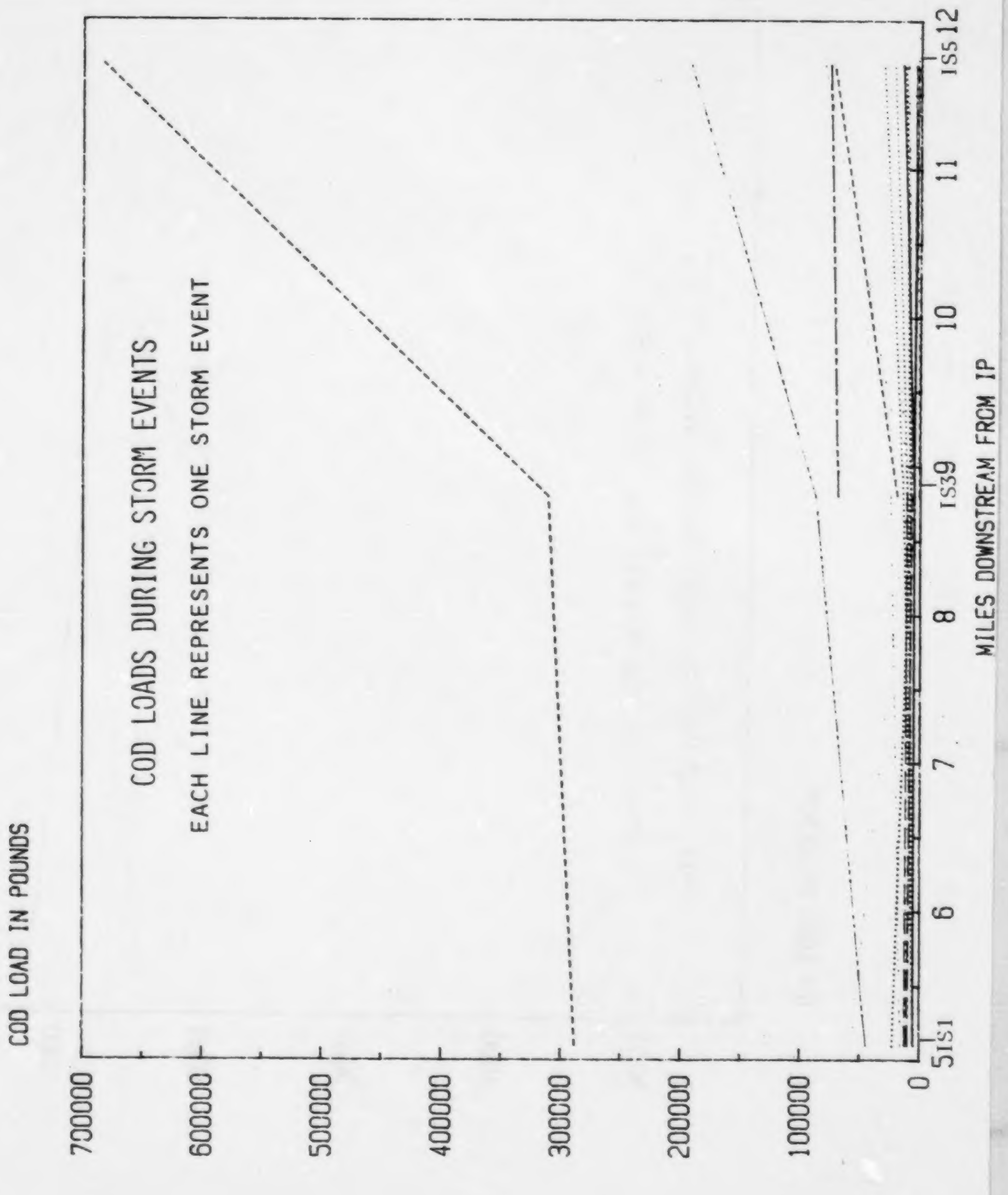

COD LOAD IN POUNDS
COD LOADS DURING STORM EVENTS
EACH LINE REPRESENTS ONE STORM EVENT
700000
600000
500000
400000
300000
200000
100000
0
5
IS1
6
7
8
IS3
9
10
11
IS5
12
MILES DOWNSTREAM FROM IP

FIGURE 3.4

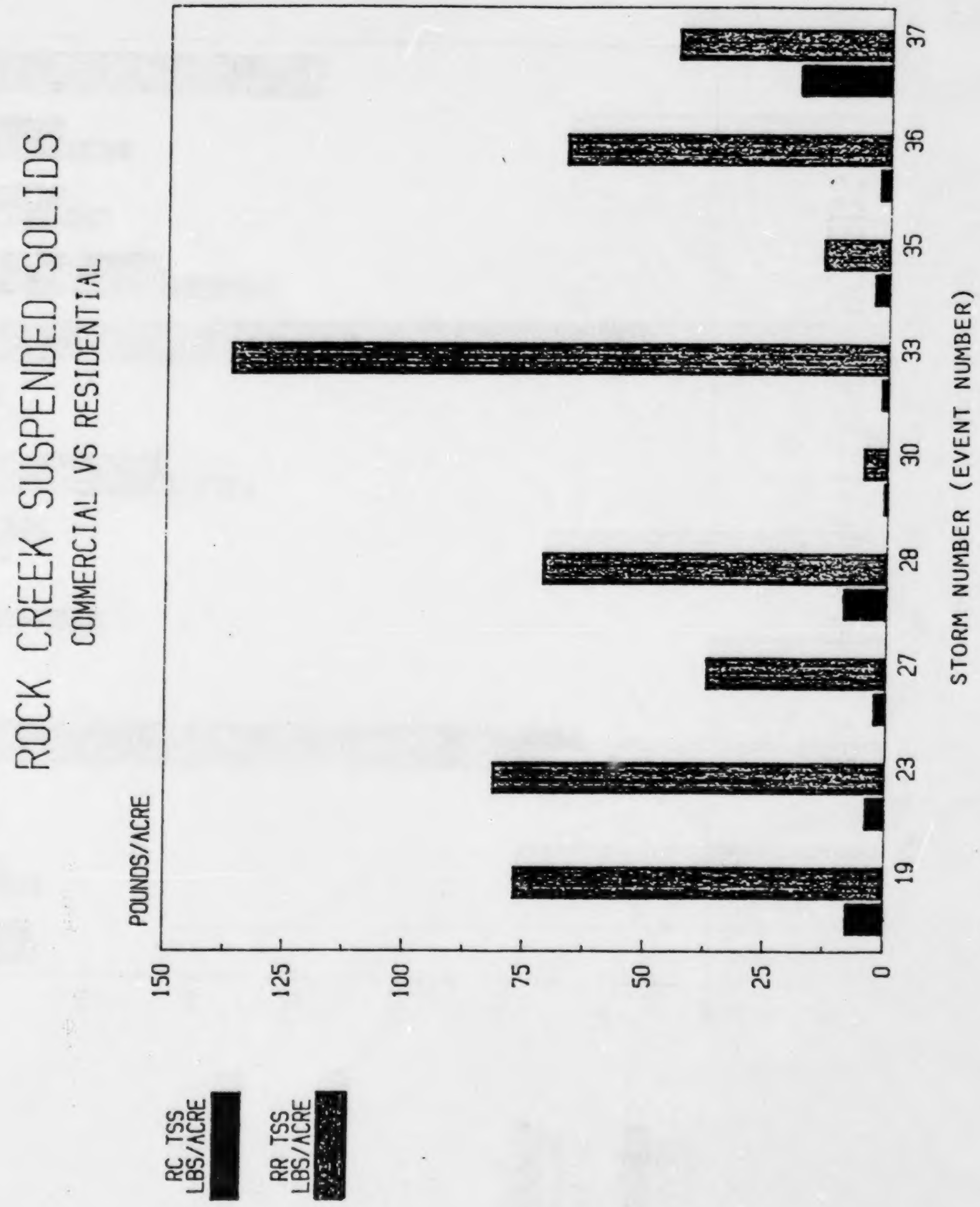

ROCK CREEK SUSPENDED SOLIDS
COMMERCIAL VS RESIDENTIAL
POUNDS/ACRE
150
125
100
75
50
25
0
19
23
27
28
30
33
35
36
37
STORM NUMBER (EVENT NUMBER)
RC TSS LBS/ACRE
RR TSS LBS/ACRE

FIGURE 3.5

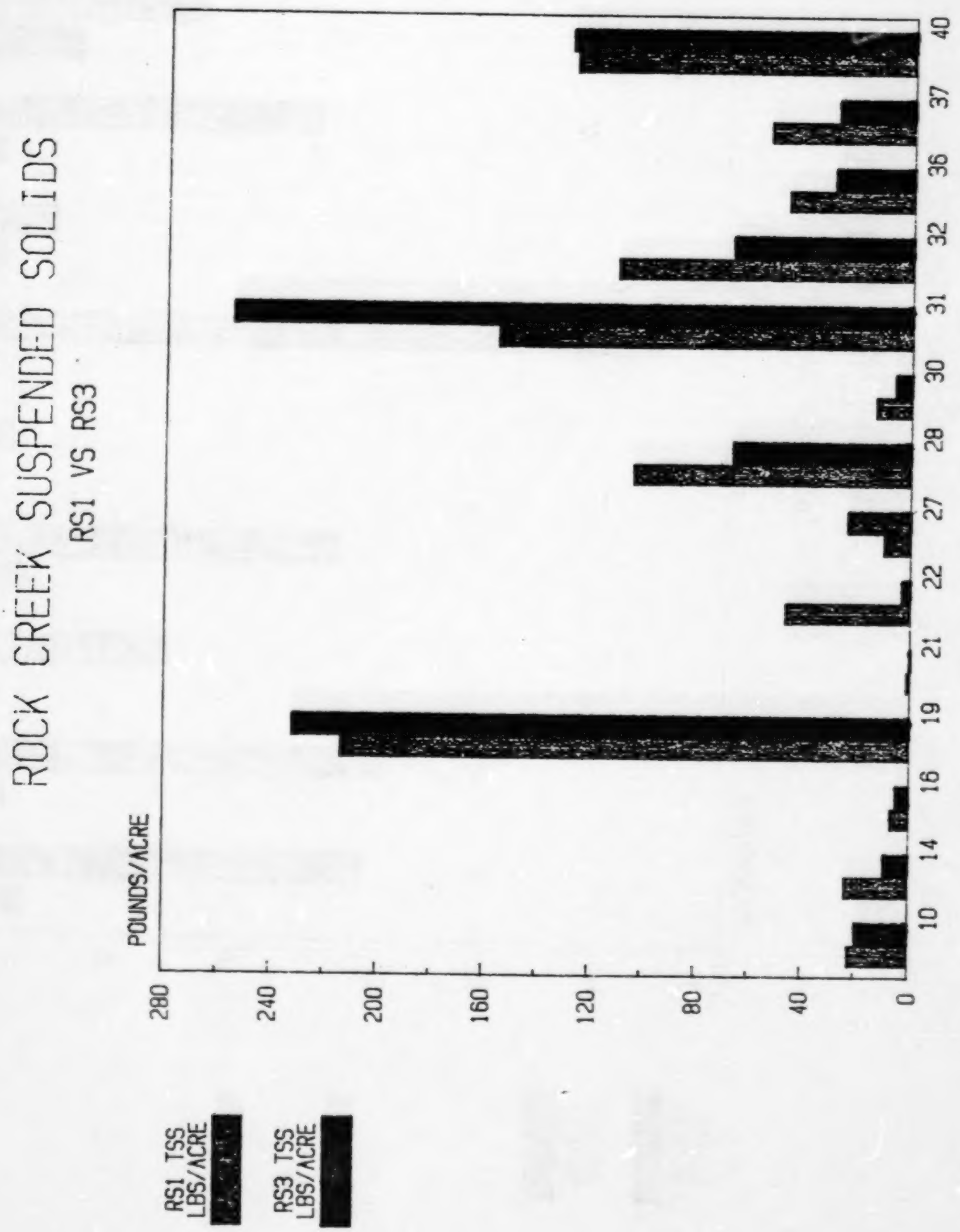

ROCK CREEK SUSPENDED SOLIDS
RS1 VS RS3
POUNDS/ACRE
0
40
80
120
160
200
240
280
10
14
16
19
21
22
27
28
30
31
32
36
37
40
STORM NUMBER (EVENT NUMBER)
RS1 TSS LBS/ACRE
RS3 TSS LBS/ACRE

FIGURE 3.6

sediment loads were higher at station RS3 for larger events. Normalized loadings can only be compared between stations for corresponding or similar storms. It would be incorrect, to compare the normalized TSS load at RS1 for event 10 with the normalized TSS load at RS3 for event 19, a much larger storm.

Normalized loads require further adjustment to account for the variability of sampled storms representing the different stations. For instance, if primarily large storms were sampled at a site, the associated pollutant mass loads and normalized loads would be higher than if smaller storms had been sampled. Therefore, all measured pollutant loads for each parameter were summed, and converted to an annual basis for each site. This was done by determining the percentage of a normal yearly cycle of storms that was sampled at each site and dividing the summation of the pollutant mass loads by this percentage. (This procedure is explained in detail in section 1.4.2.) Normalized annual loads provide the best means for comparing pollutant contributions from areas of different land uses.

An accurate extrapolation from event loadings to annual loadings requires that the set of sampled storms be representative of a typical annual series of storms at each station. Both the characteristics of the storms sampled and the sheer number of storms sampled influence the extent to which a typical annual series of storms is represented. During the NURP study, an attempt was made to sample a representative distribution of storms, including events of low, medium, and high rainfall amounts and intensities. The primary goal was to sample as many events as possible at each site, with an emphasis late in the study to sample larger events which were not represented in the early sampling. As the number of storms sampled increases, the degree to which a typical annual cycle of storms is represented should also increase, and the accuracy of the extrapolation from event loadings to annual loadings should improve. An estimation of the percent of a typical annual series of storms which was sampled at each site is presented in Table 3.7. These values are based on the percentage of annual runoff associated with the sampled events at the major stream sites (IS1, IS3, IS5, RS1, RS2, RS3), and on the percentage of annual precipitation associated with the sampled events at the tributary and land use sites.

Table 3.7
Percent of Annual Storm Cycle Sampled

Runoff Ratio			Precip Ratio		
Station	Number of Events Sampled	Annual Percent	Station	Number of Events Sampled	Annual Percent
IS1	24	32.5	IS2	10	20.1
IS3	29	42.4	IS4	20	34.4
IS5	25	40.9	IC	25	40.8
RS1	20	21.8	II	22	34.4
RS2	9	8.7	IR	16	29.8
RS3	21	27.3	RC	19	41.1
			RR	17	47.0

The number of storms sampled at RS2 was relatively small, resulting in a limited data base from which to extrapolate annual loadings.

An additional urban annual load was determined for Indian Creek. This was calculated by subtracting the total annual load (pounds per year) at IS1 from the total annual load at IS5. This difference was then normalized by dividing by the basin area between IS1 and IS5 (12,936 acres). The resulting normalized annual load represents the nonpoint pollutant contribution made by the predominantly urbanized area between IS5 and IS1. It can be used to compare pollutant contributions of various specific land uses to the urban contribution as a whole.

3.2.2 LAND USE SITES

3.2.2.1 LOAD SUMMARY

Pollutant loadings did not always appear to be a direct function of the intensity of land use (Table 3.8). There was a low degree of correlation between the two commercial sites and the two residential sites. This can be expected due to the difference in basin characteristics. The commercial site in Overland Park (IC) is a large mall type, in contrast to the mixture of strip commercial and residential uses found in the Independence commercial site (RC). The Independence residential site (RR) is characterized by smaller lots drained by natural streams with steeper channel slopes. The Overland Park residential site (IR) is characterized by large lots draining into concrete lined channels. These types of factors seemed to be better indicators of loadings than did the general land use characterization.

The hydrological characteristics of the land use sites were compared (Table 3.9) using data derived from the NURP study. The percent of impervious area at IC resulted in high runoff-precipitation ratios. A high runoff ratio was also observed at II. Annual runoff volumes calculated for IC and II were much higher than the other land use sites. None of the land use sites experienced any significant base flow. Maximum peak flows reported for these sites reflect only storms measured during the NURP study, and are not based on historic data. The reported peak flow is a measure of the largest storm monitored rather than of the largest flow which could be expected. Average rainfall amounts per event were slightly higher at the Rock Creek sites, reflecting a greater distribution of large storms over Independence during the project. This could have increased runoff precipitation ratios for the Rock Creek land use sites relative to the Indian Creek sites.

Table 3.8
Land Use Stations Nonpoint Source Loading Rates
(lb/acre/yr)

	II	IC	IR	RC	RR
TSS	670	460	64	280	2590
TP_{Tot} as P	2.6	1.3	.65	.53	5.2
TP_{Sol} as P	1.1	.42	.18	.13	.33
PO_4as P	.67	.62	.16	.08[3]	.30
Total N[1] (Table 3.10)	8.8	9.9	3.8	.74[2]	2.6[2]
COD	287	240	130	88	281
BOD	78	28	19[3]	11[3]	7.5[3]
Cl^-	136	190	38	8.8	26

[1] - calculated
[2] - estimated
[3] - based on fewer than 6 events

Table 3.9
Hydrological Summary
Land Use Sites

	IC	II	IR	RC	RR
Annual Runoff Volume (ft^3)	5.1×10^6	6.3×10^6	6.1×10^5	5.2×10^5	8.6×10^5
Average Base Flow (cfs)	0	.2	0	0	0
Max. Monitored Peak Flow (cfs)	74	34	17	29	12
Average Monitored Rainfall of Event (inches)	0.79	0.77	0.80	0.93	0.97
Average Runoff/Precip Ratio (in/in)	.53	.48	.06	.08	.09
Watershed Area (acres)	58	72	63	36	58
Percent Impervious	93.1	44.4	34	69.4	37.9

Suspended Solids

TSS annual loadings were higher at RR than at any other station. One factor involved was a very high TSS concentration measured for a storm event occurring on May 15, 1982. The measured precipitation for this event was 1.21 inches, and the associated TSS EMC was 11,560 mg/l, twice as high as any other events at this station. The average TSS EMC at RR prior to this event was 1400 mg/l. Very high concentrations of total phosphorus (14.6 mg/l) and COD (1560 mg/l) were also measured from this storm. These laboratory analyses were run twice to verify the high sample concentrations. This single event greatly increased the calculated annual loadings at RR for these parameters; exclusion of this event would have resulted in a calculated annual TSS loading at RR of 1460 instead of 2590 lb/acre/yr. Even this loading is high relative to the other land use sites and is probably due to the eroding swales and channel banks draining this steep area.

TSS loadings were substantially lower at the other land use sites. Of those remaining, the Indian Creek industrial site (II) had the highest TSS loading, followed by IC and RC. The well maintained basin above station IR had the lowest TSS loading of any of the land use sites, almost forty times lower than the annual RR load.

Nutrients

The phosphorus loadings at the land use sites showed a strong correlation with the suspended solids loadings. Phosphorus loadings ranged from 0.2 to 1% of the TSS loading for the five land use sites. Station RR showed the highest phosphorus load, followed by II, IC, and IR. Station RC had the lowest phosphorus loading, although the percentage of TSS loading this represented was the same percentage as at RR. Station IR displayed the highest phosphorus load expressed as a percentage of TSS load of any of the land use sites. However, the total nitrogen load at IR was also proportionately higher than at the other stations. Both the high phosphorus and high nitrogen loads at IR are likely due to the application of lawn fertilizers by homeowners in the watershed.

The soluble phosphorus loads ranged from 25 to 42 percent of the total phosphorus loads, with the exception of RR, where only 6 percent of the total phosphorus was in soluble form. This was due primarily to the influence of the May 15, 1982 event where a high total phosphorus load was measured. Exclusion of this event results in a calculated annual total phosphorus load of 1.21 lb/acre/yr, and an annual soluble phosphorus load of 0.29 lb/acre/yr, or 24% soluble, which is similar to the other sites.

The highest total nitrogen loads were measured at the Indian Creek commercial and industrial sites (IC and II). The loads from these sites were much higher than any other land use site (Table 3.10). The various forms of nitrogen were proportioned approximately the same at the five land use sites, and followed this same ranking. For all the sites, organic nitrogen represented the largest fraction of the total nitrogen load, followed by nitrate, ammonia, and nitrite. An exception to this order was the nitrate loading at RR which was slightly higher than the other sites in terms of percent of total nitrogen.

Table 3.10
Land Use Stations Nonpoint Nitrogen Loading Rates
(lb/acre/yr)

	II	IC	IR	RC	RR
Total N[1]	8.8	9.9	3.8	.74[2]	2.6[2]
TKN_{Tot} as N	6.8	6.9	3.2	.43[2]	1.7[2]
TKN_{Sol} as N	2.5	3.0	.95	.13[2]	.50[2]
NH_3 as N	1.1	2.5	.38	.16	.18
NO_3 as N	1.9	2.9	.56	.29	.88
NO_2 as N	.07	.13	.02	.01	.01

[1] - calculated
[2] - estimated

Oxygen Demand

COD loading was highest at II, followed by RR, IC, IR, and RC. The high oxygen demand at the industrial site is probably partially due to periodic washoff of spilled corn syrup from local soft drink bottling operations (now being rectified). The high COD loading at RR is primarily due to the influence of the May 15, 1982 storm. Exclusion of this storm from the annual loading calculation results in a calculated annual COD loading of 115 lb/acre/yr, which is very close to the COD loading at IR.

In general, high COD loads were accompanied by high BOD loads, but this was not always true. RR had a high COD loading, although BOD loadings were low. BOD values at RR averaged 10.8 mg/l for the four events that this test was performed. Varying amounts of rainfall had no apparent affect on BOD/COD ratios.

Heavy Metals

The high number of lead and cadmium samples below the detection limit prevented an accurate loading calculation for these parameters. High levels of zinc were detected at the Indian Creek industrial site (Table 3.11), probably due to the canning operations in the industrial park. Zinc loads were higher at the commercial site than at the residential site for Indian Creek. This is probably due to the presence of zinc in automobile tires and motor oil. Another source of zinc is soil erosion, which accounts for the relatively high zinc load at RR. Over 80% of the total zinc load at RR was attached to particulates.

Sodium loads were lower at the land use sites than at the stream sites, with the exception of II and IC. Deicing salts and industrial emissions are probable sources of these high sodium loads.

Iron loads were also low at the land use sites relative to the stream sites. This is probably associated with the low TSS values at the land use sites because soil erosion is the main source of iron in runoff. High iron concentrations were associated with the particulate fraction (total) and much lower concentrations associated with the soluble fraction. Station RR iron loads did not correspond to this high TSS, high iron trend. The iron loading was highest at the industrial site, again possibly due to the canning operation.

A major source of manganese is soil erosion, which explains the relatively high manganese load at RR. The majority of this manganese was associated with the particulate fraction. High copper loadings were detected at II and IC. The primary source of copper in runoff is wear of automobile parts with subsequent deposition on the pavement. This accounts for the high IC copper load, and truck traffic could possibly explain the high copper load at II.

Table 3.11

Land Use Nonpoint Metals Loading Rates[2]

(Total Metals lb/ac/yr)

	II	IC	IR	RC	RR
Lead$_t$	.002-.56	.004-.60	< .04[1]	.11-.15	.34-.36
Lead$_s$	.0002-.56	.0003-.60	< .04[1]	.01-.05	.01-.03
Cadmium$_t$	.0005-.52	.0004-.72	< .30[1]	.0006-.15	.002-.04
Cadmium$_s$	.0003-.60	.0004-.73	< .31[1]	.0007-.01	.001-.04
Copper$_t$	.10-.60	.13-.80	.008-.30	.04-.19	.10-.13
Copper$_s$	.09-.66	.11-.79	.006-.31	.03	.04-.07
Zinc$_t$	6.8	1.5	.41	.62	.90
Zinc$_s$	1.3	1.2	.27	.23	.17
Sodium$_t$	113	74	.11	6.2	15
Iron$_t$	56	13	5.0	9.9	35
Iron$_s$	1.8-2.0	2.1-2.4	.10-.32	.48	.64
Manganese$_t$	.76-.87	.27-.56	.18	.31-.34	3.8
Manganese$_s$	.14-.28	.15-.33	.04-.11	.03	.04-.05

[1] All samples below lower detection limit of instruments

[2] For explanation of values, refer to Section 1.4.3.2

3.2.1.2 LOAD-RUNOFF CURVE ANALYSIS

Three simple regression models were applied to loading data for four parameters at the land use stations. Ordinary linear regression, linear regression forced through the origin, and a log-log regression (power equation) were used. The linear regression forced through the origin showed the best fit with the data for most of the regressions, and was used as a simple loading model to calculate annual pollutant loads from each site. These annual loads were compared to average loads calculated using the standard cumulative load technique (Section 1.4.3). The regression model loads were generally lower and within 50% of the cumulative load technique.

Simple regression calculations are used to smooth out highly variable data and to express data as a weighted average. Regressions of nonpoint source data have been performed in many ways, such as sample concentration vs. flow or concentration vs. precipitation. The most common use, however, is probably a regression of pollutant load on runoff. This produces an equation of a line:

$$y = m x + I \qquad (m = \text{slope}, I = \text{intercept})$$

Variable y is a function of load (in pounds per acre) and x is a function of runoff volume (in ft^3).

Several assumptions are required to apply statistical comparisons to regression analysis:

- For any x (runoff) the distribution of y (pollutant load) is normal.
- The standard deviation of the y distribution is the same for any x value.
- The x,y ordered pairs represent random and independent samples.
- The x values are constant and are not subject to sampling error.

Although all of these assumptions are rarely met, regression analysis can provide a simple means to statistically compare and average data. Different types of linear regressions can be developed to determine the best model for the available data.

For the NURP analysis, three types of regression models were developed and compared.

First an ordinary linear regression was developed:

$$L = (m \cdot V) + I$$

L = Pollutant loads (pounds per acre)
V = Runoff volume (cubic feet)
m = Regression slope (pounds per acre per cubic foot)
I = Regression intercept (pounds per acre)

Next, this regression was modified by assuming that at zero runoff volume no pollutant loads were generated. The regression was calculated by forcing the regression line through the origin. In this use, the form of the equation was the same as the first regression except the intercept was zero.

The third regression was performed by taking logrithmic transformations of both the pollutant load and runoff data. A linear regression was performed on this data to develop a straight line equation.

$$\ln(L) = m \cdot \ln(V) + I$$

This equation can be represented as a power equation in the form of:

$$L = V^m \cdot e^I$$

These three regression models were developed from TSS, TPT, TPS, and COD data at each of the five land use sites (II, IC, IR, RC, and RR). Each regression represented a particular pollutant at a single site. The least squares fit method was used to develop the linear equations. The coefficients of determination, (r^2) of each regression were determined to compare the suitability of the equations to the data. A coefficient of .75 means 75% of the variability of the data is explained by the regression equation; a coefficient of .10 means only 10% was explained.

A complete tabulation of the coefficients of determination for all of the regressions is shown in Table 3.12. The linear through origin regression had higher coefficients (r^2) and explained more of the data than either the linear or log-log regression. The linear through origin technique had higher r^2 values than the ordinary linear method for all but one of the twenty regressions. The log-log method showed better r^2 values than the ordinary linear method, but when compared to the linear through origin, had higher r^2 values in only four of the twenty regressions. The averages and ranges of the r^2 values are shown in Table 3.13. The superior fit of the linear regression forced through the origin is probably due to the assumption that there is no load at zero flow. This assumption, based on a physical condition of pollutant loadings, removes some statistical uncertainty in the data.

Table 3.12
Comparison of Three Regression Methods
Coefficients of Determination (r^2)

		IC	II	IR	RC	RR	Mean all Stations
TSS	Ordinary Linear	.28	.88	.58	.48	.14	.47
	Linear Through Origin	.43	.87	.74	.72	.35	.62
	Log-Log	.48	.60	.69	.68	.78	.63
TPT	Ordinary Linear	.56	.04	.90	.91	.48	.58
	Linear Through Origin	.78	.40	.94	.96	.57	.73
	Log-Log	.49	.40	.41	.91	.84	.58
TPS	Ordinary Linear	.51	.00	.92	.89	.78	.62
	Linear Through Origin	.75	.01	.95	.96	.91	.77
	Log-Log	.46	.26	.75	.84	.93	.60
COD	Ordinary Linear	.49	.58	.78	.60	.11	.56
	Linear Through Origin	.73	.63	.84	.74	.26	.69
	Log-Log	.59	.89	.70	.77	.76	.68

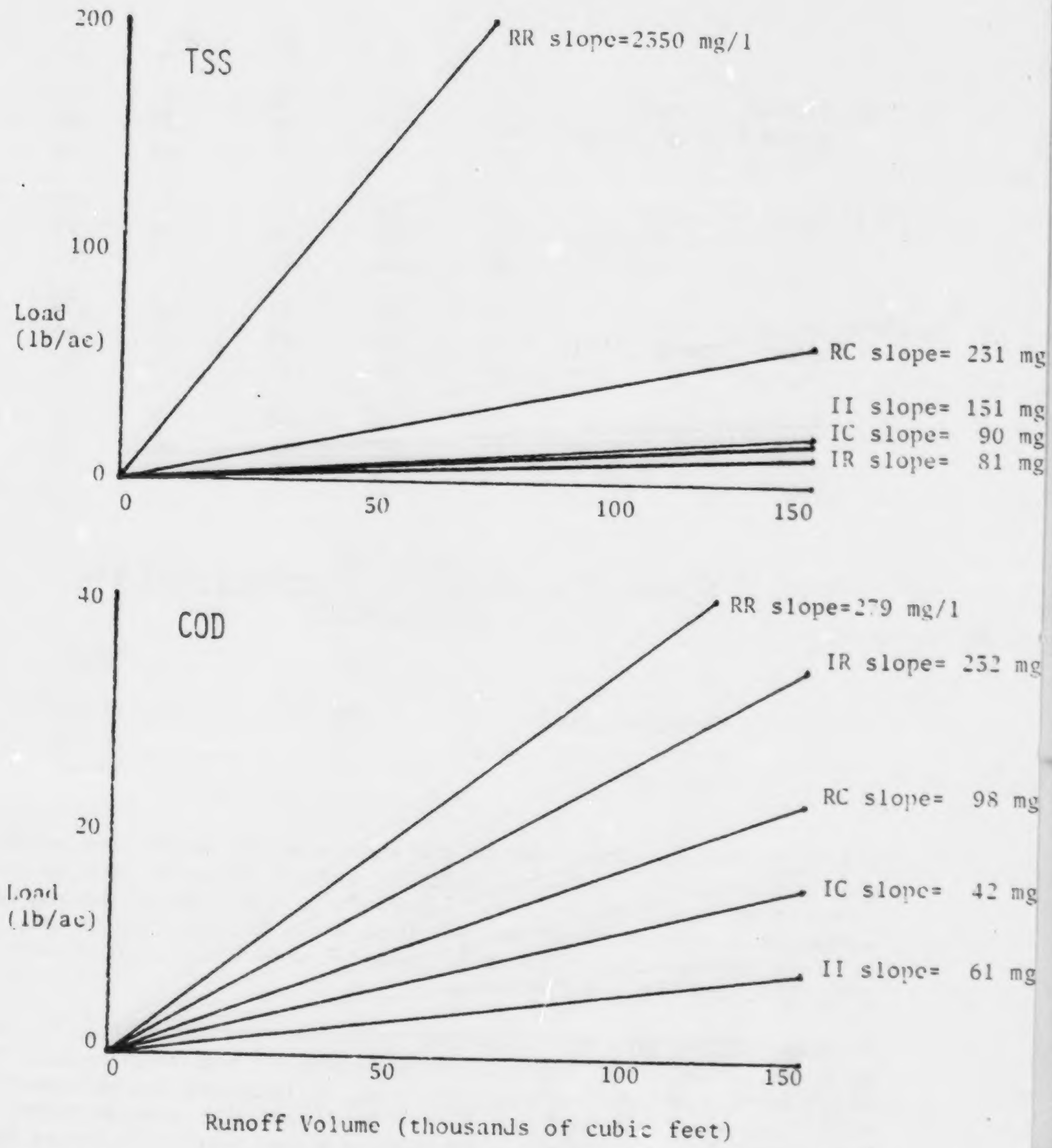
Table 3.13
Summary of Coefficients of Determination (r^2) from All Regressions

	Mean	Range
Ordinary Linear	.56	.47-.62
Linear Through Origin	.70	.62-.77
Log-Log	.62	.58-.68

The linear through origin regressions were selected to be used as the simple loading model. This model calculates an average pollutant load (in pounds per acre) carried in a given volume of runoff (ft^3). The slope of the regression line represents an average runoff concentration and is in concentration units that can be converted to mg/l. Figures 3.7 and 3.8 show load-runoff curves for TSS, COD, TPT, and TPS for five sites.

Although loading data from individual storms was used to develop the regression equations, annual loads can be calculated using the regression model. The load-runoff slope produces an annual load when multiplied by the catchment's annual runoff volume. The annual runoff volumes at each site were estimated from the NURP runoff data by multiplying the average annual rainfall (40 inches) by average runoff/rainfall ratios.
Figure 3.7

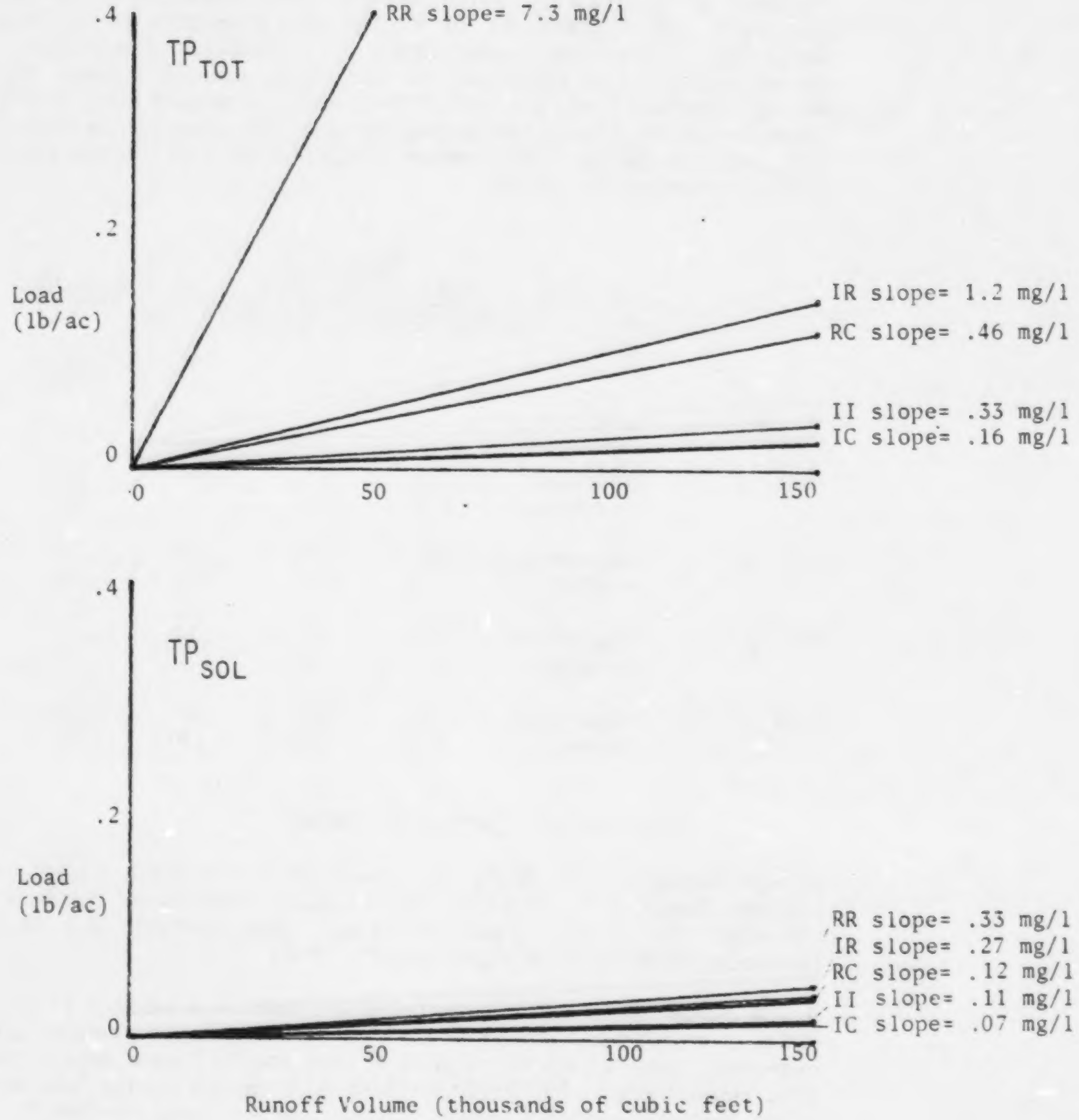
LOAD-RUNOFF CURVES FORCED THROUGH ORIGIN



Note: Slopes of regressions have been converted from lbs/acre/ft^3 to mg/l by multiplying by basin area and a conversion factor.

FIGURE 3.7

LOAD-RUNOFF CURVES FORCED THROUGH ORIGIN



Note: Slopes of regressions have been converted from lbs/acre/ft^3 to mg/l by multiplying by basin area and a conversion factor.

FIGURE 3.8

The loading data from the simple loading model (linear regression forced through the origin) was compared to the loading data presented earlier (developed from cumulative storm loads and ratios of measured precipitation to annual precipitation). The regression loading model predicted lower loads than the averaging method in all but two of the twenty compared loads (Table 3.14). The model showed an average percentage error of 25% when compared to the averaged data and the percent differences ranged from 55% underprediction to 43% overprediction by the model.

Table 3.14
Comparison of Annual Loads from Linear Regressions and Averaging Method (lb/acre/yr)

Parameter	Method	II	IC	IR	RC	RR
TSS	Regression	655	437	44	168	1923
	Average	670	460	64	280	2590
TPT as P	Regression	1.45	.77	.56	.33	5.9
	Average	2.6	1.3	.65	.53	5.2
TPS as P	Regression	.50	.32	.15	.08	.27
	Average	1.1	.42	.18	.13	.33
COD	Regression	265	203	127	126	228
	Average	287	240	130	88	281

3.2.3 ROCK CREEK STATIONS

A high degree of variability was observed in the Rock Creek stream station loadings (Table 3.15). Station RS2 exhibited inconsistent loadings compared to the other two sites. These differences were probably due to sampling and flowmetering difficulties experienced at RS2.

A low number of events, representing less than nine percent of a typical annual series of storms was sampled at RS2. By comparison, the percentages of a yearly hydrologic cycle of storms sampled at RS1 and RS3 were approximately 22% and 27%, respectively. The resulting data base generated for RS2 was too limited to extrapolate accurate annual loadings which were similar to the loadings generated at RS1 and RS3. An annual loading calculation for RS3 based on the same limited number of events as RS2 would have produced an estimated annual TSS loading of 2000 lb/acre/yr instead of 5000 lb/acre/yr. This suggests that a monitoring program should try to sample at least 20% of the year's runoff or perform statistical analysis to determine a representative annual distribution of a fewer number of storm events for sampling. The RS1 and RS3 data were much closer and reflected better monitoring conditions.

Table 3.15
Rock Creek Stream Nonpoint Loading Rates
(lbs/acre/yr)

Parameter	RS1	RS2	RS3
TSS	3800	1800	5000
TP_{tot} as P	3.8	2.9^3	4.2
TP_{sol} as P	.45	$.32^3$	.36
PO_4 as P	.42	$.20^3$	.32
Total N^1	6.5^2	4.7^2	6.5^2
COD	207	256	380
BOD	37^3	40^3	37^3
Cl^-	77	159^3	130

[1] - calculated
[2] - estimated
[3] - based on 6 or fewer events

A hydrological summary of the Rock Creek stream sites is presented in Table 3.16, describing the characteristics of the three sites. Annual runoff volumes and average base flows were determined from 7 years of USGS flow data at RS1. Maximum peak flow, average rainfall, and average runoff-precipitation ratios were determined from NURP data. The amount of rainfall per event was similar at all three sites, averaging just over one inch. The runoff-precipitation ratios were higher at the downstream sites.

Table 3.16
Hydrological Summary
Rock Creek Stream Sites

		RS1	RS2	RS3
Annual Runoff Volume	(ft^3)	1.14×10^8	1.67×10^8	2.13×10^8
Average Base Flow	(cfs)	1.0	1.5	1.75
Maximum Monitored Peak Flow	(cfs)	255	305	564
Average Monitored Rainfall	(inches)	1.04	1.03	1.03
Average Runoff/Precip. Ratio	(in/in)	.12	.16	.16
Watershed Area	(acres)	3045	4624	5566
Percent Impervious		37.2	36.1	35.3

Descriptions of individual pollutant annual loads (in lbs/acre/yr) follows.

Suspended Solids

The most significant aspect of Rock Creek pollutant loads were the very high suspended sediment loads. These loads were two to five times larger than the Indian Creek loadings, indicating a high degree of erosion occurring in the steep, fully urbanized Rock Creek watershed. The loadings per acre in the upper basin (Station RS1) increased by a third at Station RS3, which had the highest annual TSS loading of any Kansas City area NURP station (5000 lb/acre/yr). This loading is close to loadings reported from some intensely cultivated agricultural areas.

Nutrients

Total phosphorus loads were also high, and more than 80% of this was transported as insoluble phosphorus attached to sediment. The Rock Creek particulate phosphorus load equalled or exceeded the Indian Creek loads. As with TSS, a significant variation of the RS2 TPT load was observed when compared to the upstream and downstream stations.

Total nitrogen data for Rock Creek were calculated using estimated organic nitrogen data; laboratory difficulties prevented the analysis of sufficient accurate Kjeldahl nitrogen samples. Estimated organic nitrogen values taken from the IS4 Indian Creek data were combined with the available RS2 values for ammonia, nitrate, and nitrite to calculate total nitrogen. The resulting values were close for each of the three stations and were generally lower than the Indian Creek stations (Table 3.17).

Table 3.17
Rock Creek Stream Nonpoint Nitrogen Loading Rates
(lbs/acre/yr)

Parameter	RS1	RS2	RS3
Total N[1]	6.5[2]	4.7[2]	6.5[2]
TKN_{tot}	4.6[2]	3.4[2]	4.5[2]
TKN_{sol}	1.4[2]	.81[2]	1.4[2]
NH_3	1.4[3]	.15[3]	1.3
NO_3	1.9	1.3[3]	2.0
NO_2	.03	.03	.03

1 - calculated
2 - estimated
3 - based on 6 or fewer events

Oxygen Demand

The divergent loading trends at RS2 were repeated with the BOD data. Loads were the same at Stations RS1 and RS3 (37 lbs/acre/year). The COD loadings were more inconsistant and generally increased from RS1 to RS3. The COD and BOD loads were higher in Rock Creek than Indian Creek.

Heavy Metals

Sodium, zinc, iron, and manganese were usually found above the detection limits for samples run on both atomic absorption instruments and provided fairly reliable loading data. Manganese and iron increased at the downstream stations, while sodium and zinc were more variable between the three stations (Table 3.18). Lead, copper and cadmium data were usually near or below the detection limits.

Table 3.18
Rock Creek Stream Nonpoint Metals Loading Rates[2]
(Total Metals lb/acre/yr)

Parameter	RS1	RS2	RS3
Lead$_t$	.39-.44	.43	.64-.66
Lead$_s$	.02-.06	.05	.03-.05
Cadmium$_t$	.003-.21	< .46[1]	.006-.24
Cadmium$_s$	.005-.01	< .22[1]	.005-.02
Copper$_t$	.17-.36	.13-.58	.56-.79
Copper$_s$	.16	.08-.28	.12
Zinc$_t$	2.3	.58	1.4
Zinc$_s$	.29	.82	2.0
Sodium$_t$	57	57	53
Iron$_t$	56	43	120
Iron$_s$	1.6	1.0-1.2	1.8
Manganese$_t$	3.7	2.3	6.2
Manganese$_s$	.12-.13	.12-.18	.18

1 - All samples below lower detection limit of instruments
2 - For explanation of values, refer to Section 1.4.3.2

3.2.4 INDIAN CREEK STATIONS

Pollutant loadings for the three major stream sites (IS1, IS3, and IS5) were generally higher than the tributary sites (IS2 and IS4) (Table 3.19). This is probably due to the relatively high TSS loads and the pollutants attached to particulates found at the major stream sites. Phosphorus, nitrogen, and COD loads all correlated strongly with TSS loads.

Station IS3 produced several instances of inconsistent data when compared to the upstream and downstream stations. As with Station RS2, difficult monitoring conditions increased the variability and uncertainty of data from this station.

Table 3.19
Indian Creek Nonpoint Source Loading Rates
(lb/acre/yr)

	IS1	IS3	IS5	IS4	IS2	IS5-IS1[3] Urban
TSS	1800	1100	1300	950	1200	870
TP_{tot} as P	4.0	2.0	2.5	1.2	1.5	1.2
TP_{sol} as P	.83	.74	.45	.28	.11	.13
PO_4 as P	.68	.58	.60	.20	.07	.53
Total N[1]	17	8.2	11	6.6	10	5.9
COD	340	190	250	140	160	170
BOD	25	25	32	23[2]	23[2]	38
Cl^-	50	51	78	69	57[2]	102

1 - calculated
2 - based on 6 or fewer events
3 - station IS5 load (lbs/yr) - IS1 load (lbs/yr) and normalized to urban watershed area between IS1 and IS5

Hydrological characteristics of the Indian Creek sites were compared in Table 3-20. Annual runoff volumes and average base flows for the major stream sites (IS1, IS3, and IS5) were determined using USGS flow records at IS3. The remaining values presented were estimated from limited NURP data. Annual runoff volumes, average base flows, and maximum peak flows increased with increasing drainage area. Rainfall amounts averaged approximately 0.88 inches for the events sampled for all stations except for IS4, which was slightly lower. These values were lower than the average rainfall amounts measured at the Rock Creek stream sites.

For the major Indian Creek stations, runoff-precipitation ratios increased with increasing urbanization. IS2 displayed the highest runoff-precipitation ratio of any of the Indian Creek sites, due to the relatively high percentage of impervious area above IS2. The percentage of impervious area above IS4 was also very high, resulting in a high runoff-precipitation ratio. The value of 0.18 reported for IS4 may have been depressed slightly due to the lower average rainfall amounts recorded per event at that site. Storms with lower precipitation amounts were resulted in lower runoff-precipitation ratios.

Table 3.20
Hydrological Summary
Indian Creek Stream Sites

	IS1	IS3	IS5	IS2	IS4
Annual Runoff Volume (ft^3)	3.0×10^8	5.2×10^8	9.1×10^8	1.2×10^8	4.6×10^7
Average Base Flow (cfs)	5.6	7.5	9.8	0.5[1]	0.5[1]
Maximum Monitored Peak Flow (cfs)	800	875	1270	800	584
Average Monitored Rainfall (in.)	0.88	0.89	0.87	0.87	0.75
Average Runoff/Precip. Ratio (in/in)	.11	.15	.17	.21	.18
Watershed Area (acres)	11,005	16,862	23,941	3,691	1,372
Percent Impervious	23.3	30.1	31.8	42.2	41.1

[1] estimated values

Suspended Solids

The high sediment loads at IS1, IS3 and IS5 were probably generated from sources above Station IS1. Erosion from the agricultural areas in the upper Indian Creek basin probably caused the high loadings that were transported past IS1, IS3 and IS5. Relatively high sediment loads were also measured at Station IS2.

In general, it was found that as the degree of urbanization increased, the sediment loads per acre in the Indian Creek basin decreased. This was due to the relatively low sediment load contributed by the urban area between IS1 and IS5 compared to the loads in the less developed upper watershed.

The sediment load per acre of the urban area between stations IS1 and IS5 was less than half of the sediment load per acre above IS1; this depressed the sediment loads from the entire Indian Creek watershed. The urban loadings for the other parameters were also affected by this suspended solids trend.

Nutrients

Both total phosphorus and total nitrogen nonpoint loadings in Indian Creek decreased by a third to a half as the watershed was more influenced by urban sources. The reduction came mostly in the particulate phase; soluble Kjeldahl nitrogen and phosphorus loading reductions were relatively small for the downtream stations (Table 3.21). Nutrient loads from the completely urbanized tributary basin (Station IS4) were lower than for the mixed urban and agricultural basin upstream of IS1.

Table 3.21
Indian Creek Nonpoint Nitrogen Loading Rates
(lbs/acre/yr)

	IS1	IS3	IS5	IS4	IS2	IS5-IS1 Urban
Total N[1]	17	8.2	11	6.6	10	5.9
TKN_{tot} as N	13	5.9	8.8	3.7	9.2	5.2
TKN_{sol} as N	2.7	2.4	2.2	.97	1.6	1.8
NH_3 as N	1.1	.76	1.6	.37	.48	2.0
NO_3 as N	2.8	2.0	2.7	2.8	1.1	2.6
NO_2 as N	.37	.28	.25	.08	.03	.15

[1] calculated

Urban areas produced higher ammonia loads when compared to the mixed land uses upstream of station IS1. Despite the reduction in total nitrogen loads at downstream stations, the additional urban areas between IS1 and IS5 had twice the ammonia load as IS1. Although the urbanized tributary basin (IS4) or the residential site (IR) did not reflect these high ammonia loads, the larger Rock Creek stream station showed similar loads:

Basin	Ammonia Load (lb/acre/yr)
IS5-IS1 (main channel)	2.0
IS4 (tributary)	.37
RS3 (main channel)	1.3
IR	.38

This suggests either an underepresentation of IS4 and IR loads or the presence of a process affecting larger basins. The washout of accumulated benthic material (either natural or man made) may be one mechanism for these high main channel station loadings.

Oxygen Demanding Substances

BOD loads were higher in the Indian Creek urban areas compared to the mixed basin upstream of IS1. The basin between station IS1 and IS5 had BOD loads very similar to the Rock Creek stream BOD loads: 38 lb/acre/yr compared to 37 lb/acre/yr. Surprisingly, the urban tributary site (IS4) BOD was close to the upstream sites IS1 and IS2 (23-25 lb/acre/yr).

COD loads decreased in the urban areas; the urbanized basins were in the 140-170 lb/acre/yr range compared to 340 lb/acre/yr at station IS1.

Heavy Metals

The urban areas increased instream concentrations of zinc, iron and sodium (Table 3.22). The zinc loading from the urban basin between IS1 and IS5 (3.7 lb/acre/yr) was almost four times higher than at station IS1 (.93 lb/acre/yr). The urbanized tributary (IS4) was between those values (1.3 lb/acre/yr), suggesting that this basin did not have an extremely high zinc source.

The urban zinc loads were largely in the soluble form, compared to the IS1 zinc loads that were almost entirely in the particulate phase. This suggests that zinc loads at IS1 are associated with soil erosion. The primary source of urban zinc loads is automobiles. The lack of complementary samples collected for total and soluble zinc analyses resulted, in some instances, in higher computer soluble zinc loading rates than total zinc loading rates.

Copper loads were also higher in the urban areas. Both the large urban area and IS4 loads were higher than the IS1 copper load. The lower detection limits of the instruments added a great deal of uncertainty to the copper loading rates.

Lead and cadmium data were almost always near or at the detection limits and no trends were observed. Manganese loads were slightly lower for urban areas compared to Station IS1. A large amount of the detected manganese was attached to particulates and probably associated with soil erosion.

Table 3.22
Indian Creek Nonpoint Metals Loading Rates[2]
(Total Metals lbs/acre/yr)

	IS1	IS3	IS5	IS2	IS4	IS5-IS1 Urban
Lead$_t$	< .19	< .21	< .25	< .18[1]	.002-.19	< .30
Lead$_s$	< .19	< .21	< .25	< .18[1]	.002-.19	< .30
Cadmium$_t$	< .10	< .46	< .45	< .02[1]	.0002-.51	< .75
Cadmium$_s$	< .11	< .44	< .39	< .02[1]	.0002-.53	< .63
Copper$_t$	.14-.26	.06-.54	.14-.59	.16	.05-.55	.04-.97
Copper$_s$	.05-.17	.02-.47	.03-.42	.07	.03-.55	< .73
Zinc$_t$	.93	1.2	2.4	1.6	1.3	3.7
Zinc$_s$	.20	1.9	1.7	.61	1.8	3.0
Sodium$_t$	36	49	58	36	45-46	77
Iron$_t$	165	109	155	157	46	146
Iron$_s$	.63-.77	.35-.85	.63-1.1	.75	.46-.85	.51-1.5
Manganese$_t$	5.7	2.2-2.3	4.7	7.3	1.5	3.8
Manganese$_s$	.13-.16	.83-.85	.14-.25	.82	.06-.20	.12-.35

[1] All samples below lower detection limit of instrument
[2] For explanation of values, refer to Section 1.4.3.2

3.3 POLLUTANT MASS BALANCES

Two types of analyses involving mass balances were performed using NURP loading data. Total annual loads were apportioned according to their sources for TSS, total phosphorus, total nitrogen, BOD, and COD. Rock Creek annual loadings at RS3 were divided between dry weather loadings and nonpoint source loadings. Indian Creek annual loadings at IS1 and IS5 were divided between dry weather, point, and nonpoint source contributions. A second analysis involved dividing the two study areas into representative land uses, and using the land use loading rates generated in the NURP study to calculate a composite annual nonpoint loading value which could be compared with the measured annual nonpoint loading rate determined at selected stream sites. This analysis was performed for stations

RS1 and RS3 in Rock Creek and Stations IS2, IS4, and the urban area between IS1 and IS5 in Indian Creek.

3.3.1 SOURCES OF ANNUAL LOADS

Total annual loadings at station RS3 are dominated by storm loadings (Figure 3.9). Essentially all of the annual TSS loading at RS3 occurs during periods of runoff. Over 85% of the loadings for total phosphorus, total nitrogen, COD, and BOD also occur during periods of runoff. The dry weather contribution to annual loadings is the most significant for total nitrogen; 14 percent of the annual total nitrogen loading occurs during periods of low flow.

Annual loadings at IS1 were dominated by both point and nonpoint source loadings (Figure 3.10). The dry weather loading contribution was insignificant relative to the point and nonpoint loadings, except for the annual total nitrogen load (18% from low flow). The point source contribution at station IS1 was most significant for total phosphorus, total nitrogen, COD, and BOD, ranging from 13.4 to 70 percent of the total annual loadings. The point source TSS loading accounted for only 0.6 percent of the total annual load at station IS1.

The point source phosphorus loading measured at the Blackbob wastewater treatment facility was greater than the dry weather and point source phosphorus loading measured at station IS1. It appears that a portion of the point source phosphorus loading settles out upstream of IS1. The phosphorus deposited on the stream bed is attached to sediment which is picked up during periods of high runoff and carried downstream, adding to the measured nonpoint phosphorus loading at the downstream sites. The annual nonpoint phosphorus loading presented (Figure 3.10) was reduced by the amount of annual point source phosphorus load which settles out and is washed downstream during periods of runoff. Since the point source is known to contribute more phosphorus load than is detected during dry weather at station IS1, it is impossible to determine the nonpoint dry weather phosphorus load independent of the point source phosphorus loading. The dry weather nonpoint annual phosphorus loading would be expected to be small relative to the point and nonpoint annual phosphorus loads. Due to this apparent deposition phenomenon, the ability to clearly distinguish between point, nonpoint, and dry weather loadings is diminished. This factor probably affects all parameters associated with sediment downstream of the point source.

Annual loadings at station IS5 reflect the trends found at station IS1 (Figure 3.11). Again, the point source and dry weather annual TSS loadings account for an insignificant portion of the total annual TSS loading. Dry weather loadings were most significant for total nitrogen, accounting for almost 17 percent of the annual load. As expected, the point source made a proportionately lower contribution to total annual loads at IS5 than IS1 for total phosphorus, total nitrogen, COD and BOD. However, at station IS5 the point source contribution was still significant for these parameters, ranging from 9.9 to 68 percent of the total annual loads. The annual point source phosphorus loading measured at the plant was greater than the dry weather load measured at the downstream site,

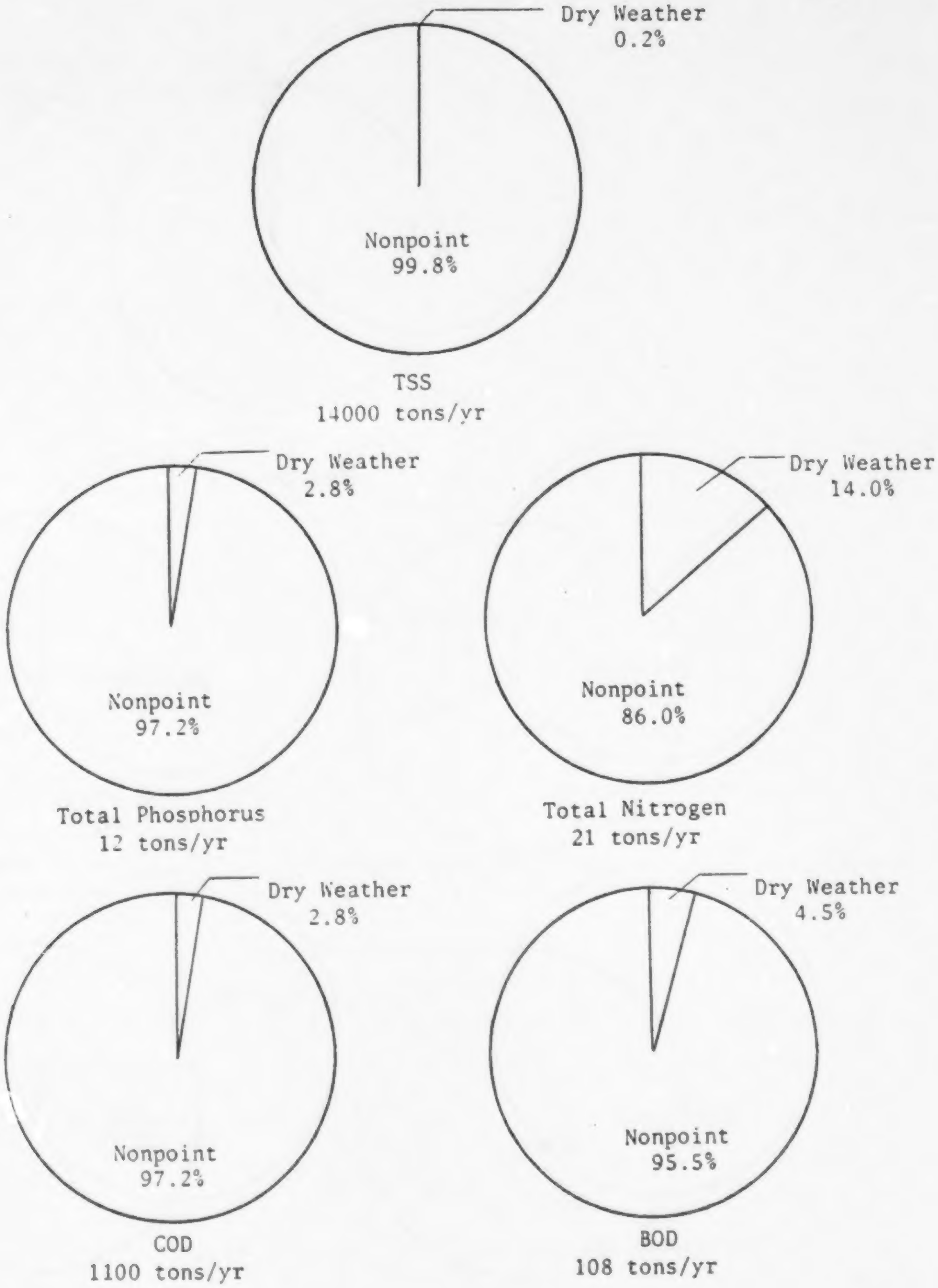


FIGURE 3.9

Rock Creek Annual Loads at Station RS3

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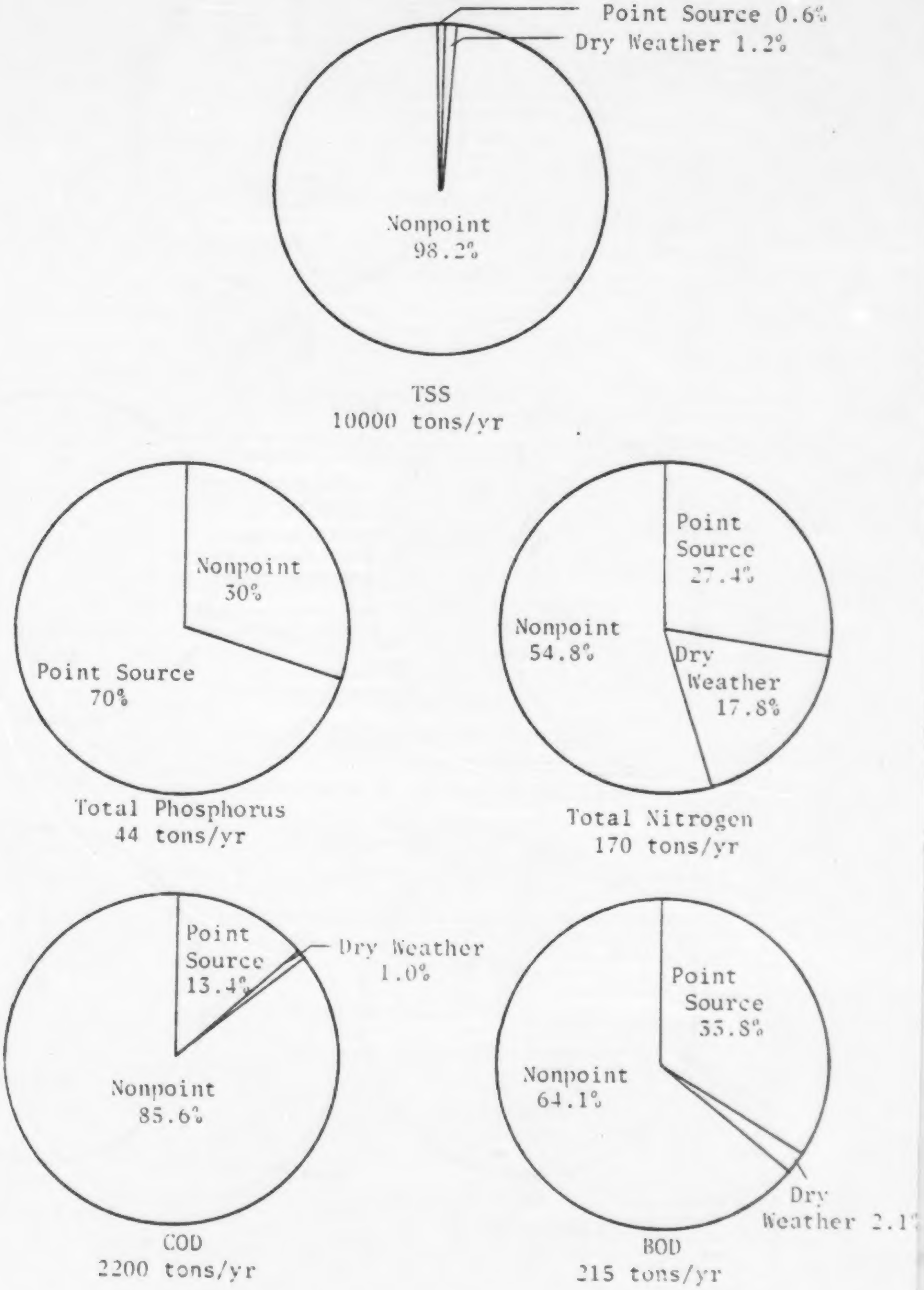
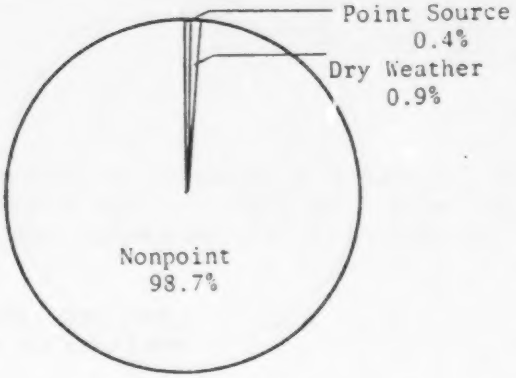
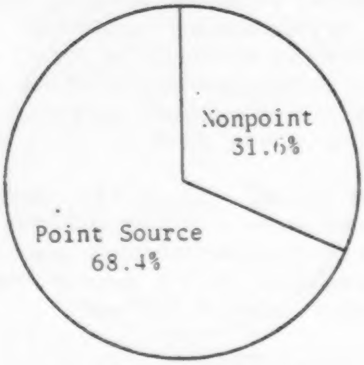


FIGURE 3.10

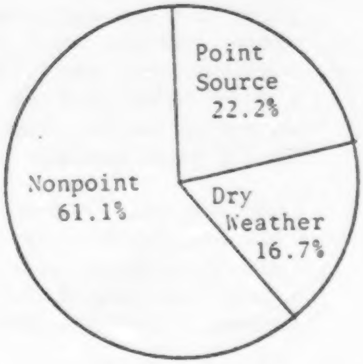
Indian Creek Annual Loads at Station IS1



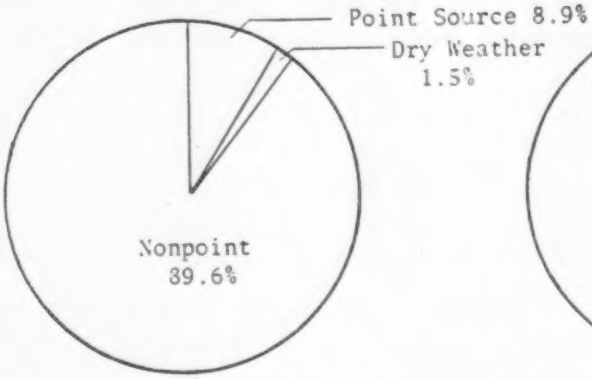
TSS
16000 tons/yr



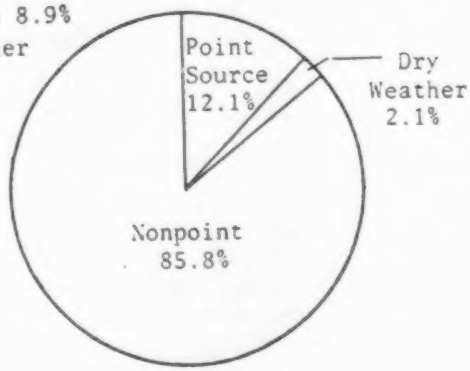
Total Phosphorus
45 tons/yr



Total Nitrogen
216 tons/yr



COD
3300 tons/yr



BOD
450 tons/yr

FIGURE 3.11

Indian Creek Annual Loads at Station IS5 again indicating that deposition of particulate phosphorus was occurring in the stream reach. The high point source phosphorus load masked the presence of any dry weather nonpoint phosphorus loading at IS5.

3.3.2 LAND USE LOADING FUNCTION EVALUATION -- "HAZARDOUS NONPOINT SOURCE ZONES"

The second type of mass balance evaluated the accuracy of applying NURP land use loading rates determined in the NURP study to calculate loads from larger mixed land use watersheds at several NURP stream stations. Basins above these stream stations were divided into representative residential, commercial, and industrial land uses. The loading rates were calculated for these watersheds by applying NURP land use loading rates to corresponding land use areas. The large watershed loading rates obtained by this calculation were then compared to the loading rates actually measured at the stream sites.

Land use was divided into five categories. Urban areas designated as "open" (parkland, public, vacant, and idle land) were combined with the residential area, and office areas were combined with commercial land use. The urban area between stations IS5 and IS1 was evaluated in the same manner as the stream stations. The breakdown of land use by station follows:

Table 3.23
Apportioned Land Use for Stream Stations

Station	Percent Residential	Percent Commercial	Percent Industrial	Percent Construction	Percent Agricultur
RS1	91.4	5.0	3.2	0.4	0
RS3	93.6	4.4	1.8	0.2	0
IS1	69.0	3.4	4.3	1.5	21.8
IS5	76.1	6.7	4.4	2.4	10.4
IS2	69.9	10.8	15.5	3.8	0
IS4	77.7	19.7	0	2.6	0
IS5-IS1 (Urban area between IS5 and IS1)	82.1	9.5	4.4	3.2	0.8

When possible, loading rates represent those measured in the same study area. Loading rates determined for station IR were assigned to residential areas in the Indian Creek basin. Station RR loading rates were assigned to residential areas in the Rock Creek basin. Station IC loading rates were assigned to commercial districts in the Indian Creek basin, and RC loading rates were assigned to Independence commercial areas. Loading rates determined at Station II were assigned to industrial areas in both the Indian Creek and Rock Creek watersheds.

Loading rates for the agricultural areas were estimated from the MARC 208 study. Average Johnson County agricultural land usage was assumed for the

Indian Creek agricultural areas. Corresponding sediment (TSS) loading rates given in the 208 study were assigned to the various agricultural land uses, and these loading functions were combined to obtain an average agricultural sediment loading rate for the Indian Creek basin. As suggested in the 208 study, it was assumed that the agricultural sediment load was predominantly topsoil containing 2000 ppm total nitrogen, 700 ppm total phosphorus, and 4000 ppm BOD. These values were used to produce the following agricultural annual loading rates for the Indian Creek watershed.

Table 3.24
Indian Creek Agricultural Loading Rates

Parameter	Annual Loading Rate lb/acre/yr
TSS	14,000
Total N	28.3
Total P	9.9
BOD	56.5

These values were used to determine the agricultural contribution for the Indian Creek stream sites. No land was used for agricultural purposes in the Rock Creek basin.

The NURP land use loading rates and the computed 208 study agricultural loading rates were used to calculate a composite loading rate for the stream station watersheds. Initially, areas designated as "under construction" were combined with the residential areas in both study areas. One early result showed that the agricultural contribution at stations IS1 and IS5 dominated the annual loading calculation. Over 90 percent of the calculated annual sediment load was due to the MARC 208 agricultural loadings and the total calculated loads were much higher than the measured loads at both stations. These problems with the agricultural loading estimate prevented the use of Stations IS1 and IS5 for this type of mass balance. The urban area between Stations IS5 and IS1 was considered separately to reduce the influence of the agricultural loads. A small amount of land is used for agriculture in the urban watershed between Stations IS5 and IS1, however the calculated loading contribution from this agricultural area is small relative to the overall urban loading.

Calculated loading rates are compared to measured loading rates for the RS1, RS3, IS2 and IS4 stream sites and the Indian Creek urban area (IS5-IS1) in Tables 3.25 through 3.29.

Table 3.25
Measured vs. Calculated Annual Nonpoint Loading Rates
Rock Creek at Station RS1

Parameter	Measured Loading Rate lb/acre/yr	Calculated Loading Rate lb/acre/yr
TSS	3800	2400
Total N	6.5	2.7
Total P	3.8	4.9
BOD	37	9.9

Table 3.26
Measured vs. Calculated Annual Nonpoint Loading Rates
Rock Creek at Station RS3

Parameter	Measured Loading Rate lb/acre/yr	Calculated Loading Rate lb/acre/yr
TSS	5000	2500
Total N	6.5	2.6
Total P	4.2	4.9
BOD	37	8.9

Calculated sediment loads were underpredicted at both Rock Creek stream sites. Total nitrogen and BOD loads were also underpredicted while total phosphorus loads were slightly overpredicted. Due to the strong influence of station RR loading rates on the calculated values (over 90% residential land use at RS1 and RS3), the calculated loading rates for the Rock Creek stream stations reflect values at RR, where BOD and total nitrogen loading rates are low, and phosphorus loading rates are high. The relatively high sediment loading rate determined at station RR did not account for the high sediment loading rate measured at either Rock Creek stream station.

Table 3.27
Measured vs. Calculated Annual Nonpoint Loading Rates
Indian Creek at Station IS2

Parameter	Measured Loading Rate lb/acre/yr	Calculated Loading Rate lb/acre/yr
TSS	1200	201
Total N	10	5.2
Total P	1.5	1.0
BOD	23	29

Table 3.28
Measured vs. Calculated Annual Nonpoint Loading Rates
Indian Creek at Station IS4

Parameter	Measured Loading Rate lb/acre/yr	Calculated Loading Rate lb/acre/yr
TSS	950	142
Total N	6.6	5.0
Total P	1.2	.78
BOD	23	21

Table 3.29
Measured vs. Calculated Annual Nonpoint Loading Rates
Urban Area between IS1 and IS5

Parameter	Measured Loading Rate lb/acre/yr	Calculated Loading Rate lb/acre/yr
TSS	870	241
Total N	5.9	4.8
Total P	1.2	.87
BOD	38	23

Calculated sediment loads were significantly underestimated at the Indian Creek stream sites using NURP land use loading rates. Calculated sediment loads accounted for only about one-half of the measured load at the Rock Creek stations, and for about one-quarter of the Indian Creek sediment load. Calculated total nitrogen and total phosphorus loads were also underestimated, although they were much closer than the sediment calculation. The calculated BOD loads showed better agreement with measured values at station IS2 and IS4, but the calculated "urban" BOD load was underpredicted.

In general, sediment loads calculated using NURP land use loading rates did not accurately predict actual loads measured at the stream sites. A possible reason for the inaccuracy is that land use loading rates determined at the three land use sites in the Indian Creek basin and at the two land use sites in the Rock Creek basin are not representaative of average loading rates for similar land uses throughout the entire basin. However, the land use sites were selected because they were typical of each study area, and they reflect the land use characteristics for their corresponding watersheds. It is unlikely that the large differences between calculated and measured loading rates is due solely to this factor.

If the NURP land use loading rates are representative of most of the similar land uses throughout the basins then a few small areas probably produce very high nonpoint source loadings. These "hazardous nonpoint source zones" can have a great impact on stream loads regardless of the relatively small area which they may occupy. Some examples of these "hazardous nonpoint source zones" could include gullies, channel erosion, pockets of agriculture, and construction sites. Channel erosion is probably more important in the steep Rock Creek basin, and agriculture is more important in Indian Creek. Both basins, however, have a significant amount of construction area, which has been shown to produce extremely high nonpoint source loading rates.

A back-calculation to determine sediment loading rates from construction sites in the two basins was performed as an example of the potential contribution which relatively small areas can make. The construction loading required to balance the calculated annual load with the measured annual load can be computed if it assumed that the land use loading rates are accurate and representative, and that any additional sediment loading above the value determined from land use loading rates originates from areas under construction. The construction area load is calculated by subtracting the calculated annual load from the measured annual load, and dividing this difference by the acres under construction in the watershed. The resulting construction loads required to balance calculated with measured loading rates expressed in tons/acre/yr are presented for the stream sites in Table 3.30.

Table 3.30
Estimated Sediment Loading Rates from Construction Areas

Station	Estimated Area Under Construction (1981) (%)	Estimated Construction Area Loading Ra tons/acre/yr
RS1	.4	193
RS3	.2	625
IS2	3.8	13
IS4	2.6	16
Urban	3.2	10

These values can be compared with the construction site loading rates of from 97 to 244 tons/acre/yr presented in the MARC Section 208 study. Computed construction area loading rates for the Indian Creek sites are much lower than the MARC loading rate while the computed construction area loading rates for the Rock Creek sites are much higher than Indian Creek values. This might be due to the much steeper channel and basin slopes in Rock Creek. The RS3 construction area loading value exceeds even the MARC Section 208 estimate, however, and suggests that not all of the excess load above that accounted for by land use loading rates is attributable to areas under construction. Other mechanisms such as channel erosion, which is visible along the steep channel, probably contribute significant amounts as well.

The potential effect of an areawide erosion control program, such as the MARC Model Grading and Sediment Control Ordinance, was examined using these construction load estimates. This was done by assuming that all loading in excess of land use loading rates originates from areas under construction, and that implementation of the erosion control program would reduce these construction loads to 5 tons/acre/yr (as recommended by the MARC ordinance). This would result in a very significant reduction in annual sediment loading rates in both Indian Creek and Rock Creek. Loading rates were calculated in the same manner as the previous loading calculation (Tables 3.25 through 3.29) except that an annual loading rate of 5 tons/acre/yr was assigned to the areas under construction indicated in Table 3.23. The resulting calculated loads and corresponding percent reductions in measured sediment loads presented in Table 3.31.

Table 3.31
Estimated Effect of Erosion Control Program

	Measured Annual Sediment Load lb/acre/yr	Etimated Annual Sediment Load with Controlled Construction Erosion lb/acre/yr	% Reduction in Annual Sediment Loads
RS1	3800	2410	20
RS3	5000	2470	50
IS2	1200	578	53
IS4	950	400	56
Urban Area IS5-IS1	870	560	36

Assumptions: * Additional measured load from mass balance originates from construction sites
* This erosion can be controlled to 5 tons/acre/yr

Not all of the sediment loading in excess of land use loading rates originates from construction areas. However, a great deal of the annual nonpoint load is probably contributed by specific hazardous nonpoint source zones of one form or another. Controlling the loadings from these small, specific areas could probably result in a significant reduction in annual stream loads.

Summary

The NURP land use loading data was used to construct a mass balance on large watersheds with mixed land uses. This loading calculation significantly underpredicted monitored sediment loads for watersheds in both Indian Creek and Rock Creek. Nitrogen and BOD calculated loads were also underpredicted but to a lesser degree, while the phosphorus predictions were relatively close.

The difference between the calculated and monitored loadings suggests small "hazardous nonpoint source zones" produce high pollutant loads that were not observed in the NURP land use monitoring. These zones might include gullies, pockets of agriculture, channel erosion or construction areas. A calculation assuming construction areas contributed all of the unaccounted difference in the previous mass balance was performed. These "estimated construction loads" were very high in Rock Creek and lower in Indian Creek. A final calculation, using these construction site assumptions, estimated reductions in annual sediment loads with an erosion control program such as MARC's Model Grading and Sediment Control Ordinance. A five ton/acre/yr performance standard on the construction site (or other hazardous nonpoint zones) would produce a large reduction in annual sediment pollutants for the cases studied.

4.0 FACTORS CONTROLLING LOADS AND PREDICTIVE EQUATIONS

A series of statistical operations were performed on the NURP data to determine what factors control the loadings of the different pollutants and to develop empirical relationships that will allow the data to be applied to similar watersheds. An Analysis of Variance (ANOVA) on the data provided a semi-qualitative assessment of the significant hydrologic and land use factors related to pollutant loadings. This information was used to develop two types of multiple regressions, stepwise and forced. The stepwise regression produced loading equations by selecting statistically significant variables from a variable list. The forced multiple regression included all the variables within accuracy tolerances in the loading equation. Both methods indicated the correlation of each individual variable to pollutant load. These correlations were used to develop watershed management principles and methods that are discussed in the Executive Summary.

The multiple regression equations had poor correlation coefficients (r^2), reflecting some unique characteristics of the NURP site data and the high variability in the data. These equations do not appear to be transferable to other locations. Because of the normality requirements of the multiple regression (logs of normalized loads were used) the resulting exponential equations were also very difficult to apply to obtain an annual load.

These restraints led to the generation of load runoff regressions through the origin, which were shown in section 3.2.1.2 to be the best simple regression model. These regressions had good coefficients of determination and provide an accurate, easy to use model of NURP pollutant loadings. To apply these empirical relationships to another watershed, a similar NURP watershed's load-runoff regression is used to estimate loads. This simple method is probably more accurate than the more sophisticated but poorly fitting multiple regression equations.

4.1 LAND USE AND HYDROLOGIC FACTORS CONTROLLING LOADS

4.1.1 ANALYSIS OF VARIANCE (ANOVA)

Loading data calculations and summaries presented in Chapter 3 show a high degree of variability in pollutant loads within and between sites. Comparisons of catchments with the same land use activities, such as the Rock Creek and Indian Creek residential sites, have indicated that land use categories alone do not accurately predict pollutant loadings from a specific site. The high variability in individual storm loading data hinders the use of simple statistical functions, such as the mean, range and standard deviation, to determine what factors control urban nonpoint source loadings. These data suggest that several secondary land use and hydrologic characteristics were important loading factors and could be used as loading predictors.

These characteristics were entered into the SPSS computer files and the basic oneway analysis of variance (ANOVA) was used to determine which of these factors, in addition to land use, had effects on pollutant loads. The analysis of variance analyzes an independent factor, such as slope for example, for its effect on a dependendent variable, such as pollutant load. The source of the variation in the loadings is partitioned into that variation within measurements from land uses with the same slopes, versus variation between measurements from land uses with differing slopes. If the variation between measurements from different slope categories is statistically greater than the variation within measurements from the same slope category, the independent slope factor is statistically significant. The conclusion from this example would be that slope, in addition to land use, contributes to variation in pollutant loading from a site. If the slope factor is not significant, the observed differences in measured loads are due to random variation and experimental error and cannot be attributed to differences in slope.

Initially the ANOVA was run on natural logs of loads (lbs/acre/event) with data divided by station for each parameter to confirm that significant differences between sites were present. Natural logs were used to satisfy the ANOVA requirement for a normally distributed data set. Next, the data were grouped according to several factors which included:

Basin Slope (%)
Channel Slope (%)
Season (winter, spring, summer, fall)
Rain Intensity (inches/hour)
Antecedent Rain Conditions (days)
Percent of the Basin with Storm Sewers (%)
Percent Development of the Basin (%)
Percent Imperviousness of the Basin (%)

The number of groups within each factor varied; the slope factor, for example, was divided into 4 categories and the antecadent rain category into 9 categories. In all cases, the entire data base for each parameter was used. The SPSS ANOVA routine analyzed these groupings to determine significant factors influencing loads. A Duncan's test analysis was also performed to determine the general nature of the relationship.

Results from the analysis of variance are presented in Table 4.1.

Table 4.1
ONEWAY ANOVA
Natural Logs of Normalized Loads of Combined NURP Data Set

Dependent Variable	Basin Slope	Channel Slope	Percent Sewered	Percent Impervious	Percent Developed	Season	Antecedent Rain	Rain Intensity
TSS	* *	*	* *	* *	* *	* *	*	
TPT				* *	* *	* *	* *	* *
TPS	* *	* *		* *	* *	*	* *	
PO_4	* *	* *	* *	* *	* *	* *	* *	
TKNT	*							
TKNS	*			*		*		*
NH_3	* *	* *	* *	* *	* *			
NO_3	* *		* *	* *	* *	* *	* *	
NO_2	* *	* *	* *	* *	* *	* *		
COD	*		*	*		* *	*	*
BOD						*	*	
Cl^-			* *	* *	* *	*		

* = .05 Factor showing relationship to loading data

* * = .01 Factor showing strong relationship to loading data

Significance at the .05 level is indicated by an asterisk (*); highly significant factors (.01) are denoted by * *. A .05 significance levels means that the probability of loadings from the different groups belonging to the same overall population is less than .05. A significance result also indicates that the variation among loads from the different groupings is at least partially attributable to the factor being examined, and cannot be totally accounted for by experimental error or random variation in urban loadings. These ANOVA results do not allow for the development of a predictive equation, which is discussed in the next section, but they do present general relationships, which are discussed below. The results from these analyses were used, however, in the development of empirical formulas from multiple regression analysis.

The results of the ANOVA on several factors are discussed below.

Basin Slope

As expected, higher basin slopes corresponded very strongly with higher sediment loads. The relationship between slope and erosion was clearly shown in the data. The nutrient data did not present such a clear trend; some soluble parameters (TPS, PO_4, NH_3, NO_3 and NO_2) showed a negative relationship with basin slope. This was largely due to the effect of II, RC, and II, which produce high soluble pollutant loads from impervious areas despite relatively low slopes.

Channel Slope

Greater channel slopes corresponded to higher sediment loads. The loading data did not show a relationship between channel slope and total phosphorus. For soluble and orthophosphate, there were significant differences between slope categories, but these did not correspond to a linear increase in load with an increase in channel slope. For NH_3, NO_3 and NO_2, the lowest channel slopes consistently corresponded with the highest nitrogen loads. This is probably related more to agricultural loads from the Indian Creek main channel stations (IS1, IS3, IS5), which have flat channel slopes, than on actual physical relationship. Channel slope showed no significant effect on BOD, COD or Cl^- loads.

Percent Storm Sewered

In general, TSS loads were highest at sites with lower percentages of storm sewered area, probably due to erosion occurring in swales (grassy yard ditches) and ditches. This finding should be evaluated with the additional factor of basin slope. Steep basin slopes consistently corresponded with high TSS loads; the Rock Creek basin has much higher average slopes than the Indian Creek basin, but also has a very low percentage of storm sewers. The apparent reduction in TSS loads with increase in percentage sewers is probably due to the combined factors of steep slope and low percentage sewers that are found in Rock Creek. The percentage of storm sewered area showed a slight relationship with some phosphorus and nitrogen loads; but no strong trend was observed. This was also true for BOD, COD and Cl^-.

Percent Impervious and Percent Developed

Differences in percentage of impervious area and percentage of developed area resulted in significant differences in almost all parameters, but the effect on the loads was variable and no clear trends were found. These two factors were strongly correlated with each other, but their effects were apparently influenced by other factors.

Season

The loads in spring and fall were higher than the summer loads for most parameters showing a significant relationship. The lower summer loads are probably related to dryer ground conditions from hot weather and more vegetation protection compared to spring or fall. This is responsible for lower runoff rates and less erosion.

Rain Intensity

High total phosphorus loads showed a relationship to high rainfall intensity. No other parameter, including TSS, showed as strong a relationship.

Antecedent Rain

Antecedent rain conditions were associated with significant differences in TSS and phosphorus, but no linear association was seen. For COD and BOD, longer antecedent rain conditions were associated with higher loads.

These analyses showed that the various land use, physical and hydrologic factors were associated with significant differences in measured loads and could explain part of the variation occurring between loads, but few clear trends from this basic ANOVA were seen. The following section examines the interaction of these variables using a multiple regression.

4.1.2 MULTIPLE REGRESSION EQUATIONS

Most of the factors analyzed in the ANOVA procedure were applied to the multiple regression; some adjustments were made to reflect the ANOVA results. Pairwise deletion of missing data was used, which enables the regression model to incorporate all existing data from a case (station event) even if one or more of the specified independent variables are missing. In contrast, listwise deletion only incorporates cases with no missing values for any of the independent variables. Two methods of generating the regression equation were used. A stepwise method was used which enters variables one at a time and examines each variable after each step for entry or removal according to specified criteria. SPSS default specifications for probability of F-to-enter (.05), probability of F-to-remove (0.1), F-to-enter (3.84), F-to-remove (2.71), and tolerance (0.01) were used to control entry and removal of variables. A forced entry method was also used which forces the regression equation to include all of the variables listed, regardless of their significance.

The stepwise regression, in combination with the correlations of each independent variable, show the important factors affecting the generation of each pollutant (Table 4.2). The higher the correlation the more important the relationship between the independent variables (land use or hydrologic factor) and the dependent variable (pollutant load). A negative correlation shows an inverse relationship, such as an increase in the concrete storm sewered area decreases erosion.

Table 4.2
Correlation Coefficients of Land Use and Hydrologic Variables to Pollutant Loads

r^2	Sediment (TSS)		Total Phosphorus		Manganese		Iron	
	Land Use	Stream	Land Use	Stream	Land Use	Stream	Land Use	Stream
> .5	**CHAN**	**P**		**P**	**CHAN**	**P**		
.4 - .5	**P** -SEW	**-SEW**	**P**		**P**			**P**
.3 - .4		BASL	**IND**		BASL -SEW		**P** **INT**	INT
.2 - .3	**BASL**	-IMP CHAN			-COM -IMP	BASL -SEW **-IMP** INT	**IND** **CHAN** COM	**-IMP**
.1 - .2			CHAN COM	**INT** IMP -SEW AG				ANT BASL
< .1	**IMP**							

BOLD represents statistically significant variable in stepwise regression

Legend:
P = Preciptation
BASL = Basin Slope
CHAN = Channel Slope
IMP = Impervious Area
INT = Rain Intensity
ANT = Antecedent Dry Period
SEW = Storm Sewered Area
IND = Industrial Area
COM = Commercial Ar
AG = Agricultural Are

Table 4.2 (cont.)

r^2	Total Nitrogen		Chemical Oxygen Demand		Zinc		Copper	
	Land Use	Stream	Land Use	Stream	Land Use	Stream	Land Use	Stream
> .5	**P** **-BASL**	**P**		**P**				
.4 - .5	SEW					**P**		
.3 - .5	-CHAN IMP		**P**	**INT**	**INT** **P**		**P** ANT	**P** **ANT**
.2 - .3		CHAN **BASL**	**IND**	**-AG**	IND	**INT** -AG	-SEW IND	
.1 - .2	INT ANT		INT	CHAN ANT IMP				INT
< .1				-SEW BASL				

BOLD represents statistically significant variable in stepwise regression

Legend:

P = Preciptation
BASL = Basin Slope
CHAN = Channel Slope
IMP = Impervious Area
INT = Rain Intensity
ANT = Antecedent Dry Period
SEW = Storm Sewered Area
IND = Industrial Area
COM = Commercial Area
AG = Agricultural Area

Two regressions were performed for each parameter for the small land use sites (< 100 acres) and the larger "stream" sites (1300-24,00 acres).

These independent variables were used for the land use site analysis:

Variable	Units	Table Abbreviation
Channel slope	%	CHAN
Basin slope	%	BASL
Storm sewered area	%	SEW
Commercial area	%	COM
Industrial area	%	IND
Impervious area	%	IMP
Rain Intensity	inches/hr	INT
Antecedent dry period	days	ANT
Precipitation of single storm	inches	P

The storm sewered area correlated very closely to the area with curb and gutter drainage; this variable reflected both factors.

The stream stations used most of these variables but replaced the specific commercial and industrial area variables (COM and IND) with the impervious area variable and:

Variable	Units	Table Abbreviation
Agricultural area	%	AG

These variables were used to reflect the very mixed, general levels of urban development in the large watersheds.

Results

The correlation of the independent variables to the pollutant loads for eight parameters are shown in Table 4.2. Underlined variables represent those determined by SPSS entry and removal criteria to be statistically significant.

Total Suspended Solids (TSS)

Both the stream sites and land use sites showed strong loading correlations with storm sewered area and basin slope. The lower the percentage storm sewered area the higher the load, showing that areas drained by swales can contribute high sediment loads. High basin slopes also contribute to higher loads. A combination of these two factors, swales and high basin slopes, probably are necessary to cause serious erosion problems. Station RC showed low to moderate loads with 50% swale drainage on the low basin slopes. Station RR had very high loads from its 100% swale drained, steep basin slope watershed.

The same land use sites showed a strong correlation between sediment and high channel slope. This is primarily due to Station RR, which had a steep natural ravine with visibly eroded banks.

Phosphorus

Phosphorus loading correlations were lower than TSS loading correlations. The land use sites showed some loading correlation to the intensity of land use and channel slope while the high stream site loads correlated with higher rain intensity, more impervious area, and less storm sewered areas. The annual loading data showed a very strong relationship between erosion and phosphorus; the regression analysis showed some but not all of the erosion factors related to phosphorus loads.

Manganese

Manganese correlated very strongly with the factors associated with sediment: storm sewered area, basin slope, and channel slope. The sediment to manganese relationship was very strong.

Iron

Iron is usually associated with erosion and sediment production. The regression analysis showed strong relationship to rain intensity for both land use and stream sites. This suggests that some washoff of accumulated material occurs or that intense erosion is required to produce high iron loads. Since most of the iron was found attached to soil particles, erosion is probably the main process. The regression data does not provide as clear an indication of the causes of iron generation as manganese or total suspended solids.

Total Nitrogen

The regression results seemed to reflect a wide variation in the data and some unique characteristics of the NURP sites. The large stream sites showed a nitrogen loading relationship with high channel slopes and basin slopes, indicating an erosion related process. The land use data showed reverse relationships with basin slope, channel slope, and storm sewered areas. This suggests a negative relationship with erosion from these sites. A higher amount of impervious area was shown to increase total nitrogen loads. This may suggest that erosion from large basins contributed much of the nitrogen load while on the small sites, accumulated nitrogen was more important. This trend is not clear, however. The estimated organic nitrogen loads in the Rock Creek data also adds uncertainty to this conclusion.

Chemical Oxygen Demand

The land use sites showed a strong relationship between industrial area and COD loads. The stream sites showed COD loading relationships with factors related to both erosion and washoff of impervious areas.

Zinc

Zinc production was related to high rain intensity, higher industrial activity, and lower agricultural activity. The low correlation with agricultural activity suggests zinc is produced more by washoff than erosion. The relationship with intensity supports this conclusion.

Copper

A strong correlation to antecedent dry periods suggests that slow accumulation of copper and washoff is the controlling process. Copper was found in low amounts during the study which also suggests a slow accumulation process is responsible.

The other metals' parameters (lead and cadmium) were not analyzed because most of the samples were below detection limits.

4.2 FORCED MULTIPLE REGRESSION PREDICTIVE EQUATIONS

The forced regression equations for the stream sites are presented in Table 4.3. The five land use sites produced inconsistant equations because of unique site characteristics and the small number of sites. The stream sites' equations are presented primarily for illustrative purposes. The regression is in the form of a power equation because log load data was used to satisfy normality requirements. Because the regressions are power equations, each yields a load from a single storm event; an annual load calculation would require summing a series of individual storm loads. Using a year's worth of precipitation in the equation would not produce an accurate annual load. For annual loads the load-runoff models (see next section) are probably more reliable and are much easier to use than the multiple regression equations.

Results of Forced Regression

Some reverse relationships are shown in the forced multiple regressions. Sediment loads are shown to decrease slightly with increasing basin slope, a condition not reflected in the individual variable correlation matrix. This trend and other reverse relationships occurred in the development of multiple regressions. All the factors together tend to distort or obscure some of the trends shown in the correlation analysis. This suggests, along with the poor fit of the regressions, that a simpler model works better for this highly variable data.

Table 4.3 Forced Multiple Regression Equations for Stream Site Data

$$\mathrm{TSS\ (lb/acre)} = \mathrm{EXP}\,[1.21\ \mathrm{P} - .097\ \mathrm{BASL} - .011\ \mathrm{IMP} - .018\ \mathrm{SEW} + 1.24\ \mathrm{INT} - .025\ \mathrm{ANT} + 2.67];\ r^2 = .42$$

$$\mathrm{TPT\ (lb/acre)} = \mathrm{EXP}\,[1.11\ \mathrm{P} + .035\ \mathrm{BASL} + .47\ \mathrm{CHAN} + .062\ \mathrm{AG} - .00059\ \mathrm{SEW} + 1.22\ \mathrm{INT} - .0037\ \mathrm{ANT} - 6.18];\ r^2 = .44$$

$$\mathrm{TOTN\ (lb/acre)} = \mathrm{EXP}\,[1.30\ \mathrm{P} - .52\ \mathrm{BASL} - .0075\ \mathrm{IMP} - .0014\ \mathrm{SEW} + 1.02\ \mathrm{INT} + .020\ \mathrm{ANT} - 1.53];\ r^2 = .63$$

$$\mathrm{COD\ (lb/acre)} = \mathrm{EXP}\,[1.03\ \mathrm{P} - .60\ \mathrm{BASL} - .067\ \mathrm{AG} - .0089\ \mathrm{SEW} + 2.48\ \mathrm{INT} + 2.43];\ r^2 = .50$$

$$\mathrm{Zn\ (lb/acre)} = \mathrm{EXP}\,[1.30\ \mathrm{P} - .11\ \mathrm{BASL} + .00044\ \mathrm{IMP} - .00065\ \mathrm{SEW} + 2.35\ \mathrm{INT} - .080\ \mathrm{ANT} - 5.49];\ r^2 = .29$$

$$\mathrm{Cu\ (lb/acre)} = \mathrm{EXP}\,[.88\ \mathrm{P} + .23\ \mathrm{BASL} - 1.05\ \mathrm{CHAN} - .079\ \mathrm{AG} + .0015\ \mathrm{SEW} + .57\ \mathrm{INT} + .072\ \mathrm{ANT} - 6.47];\ r^2 = .20$$

$$\mathrm{Mn\ (lb/acre)} = \mathrm{EXP}\,[.84\ \mathrm{P} - .18\ \mathrm{IMP} - .40\ \mathrm{AG} + 2.87\ \mathrm{INT} - .062\ \mathrm{ANT} + 5.54];\ r^2 = .85$$

$$\mathrm{Fe\ (lb/acre)} = \mathrm{EXP}\,[.75\ \mathrm{P} - .16\ \mathrm{IMP} - .33\ \mathrm{AG} + 3.60\ \mathrm{INT} + 6.71];\ r^2 = .56$$

Notes: See Table 4.2 for variable legend; units are given in text.
Some variables were excluded from regression by SPSS program because of poor regression tolerances.
These equations represent loadings from individual storms; annual loading calculations require summing loads for each of the storm events during a year.

4.3 LOAD-RUNOFF CURVE MODELS

Load-runoff curves were selected to replace the poorly fitting multiple regression curves as empirical models for transfering data to other watersheds. The load-runoff curve analysis of four parameters in Section 3.2.1.2 showed that a linear regression through the origin provided the best coefficients of determinatation (r^2). The SPSS linear regression routine was used to generate load-runoff slopes (in pounds per cubic foot of runoff) for each of the thirteen NURP sites (Table 4.4).

A loading calculation using these load-runoff curves consists of selecting one of the thirteen NURP watersheds that is most similar to the watershed to be modeled in size and especially land use. For loads from a single storm, the runoff volume from the watershed to be modeled is then calculated using a common hydrologic model (such as the Soil Conservation Service TR-55, the rational method, or a computer model) or from gaging data. The runoff (in ft^3) is multiplied by a pollutant's load-runoff slope (Table 4.4) to yield a pollutant load in pounds. The NURP data in Section 2 can be used to estimate the distribution of the pollution between chemical forms and soluble/insoluble fractions.

Annual loads can be easily calculated by obtaining the annual runoff (in ft^3) from the watershed using gaged data, hydrologic models, or estimated rainfall to runoff ratios. The runoff value is then directly multiplied by the load runoff slope as with the single storm calculation.

This type of simple model has been successfully applied to urban runoff data in many locations, and closely predicts the results from the NURP loading calculations (Section 3.2.1.2). The use of runoff volume as an independent variable allows loads to be estimated for single event and annual loadings. The amount of runoff reflects geographic, hydrologic, and land use factors, and the selection of different NURP watersheds allows further resolution for additional loading factors.

Table 4.4
Load-Runoff Curves for NURP Stations
Load Runoff Slope (lbs/ft^3 runoff)
Regression Forced Through Origin

Station	TSS	TPT ($\times 10^3$)	TOTN ($\times 10^3$)	COD ($\times 10^3$)	BOD ($\times 10^3$)	Zn ($\times 10^4$)	Cu ($\times 10^5$)	Fe ($\times 10^3$)	Mn ($\times 10^3$)
IS1	.043	.10	.56	11	.66	.42	.89	8.0	.27
IS2	.041	.058	.44	6.2	--	.59	.67	6.8	.32
IS3	.033	.076	.34	6.6	1.25	.49	2.3	3.5	.065
IS4	.024	.047	-.25	4.7	.93	.52	2.2	1.3	.045
IS5	.029	.066	.30	6.8	1.11	.73	1.8	4.5	.14
RS1	.12	.094	--	8.3	.63	.66	.73	1.1	.10
RS3	.089	.046	--	6.8	1.00	.30	1.8	3.3	.18
II	.0094	.021	.12	3.8	.34	(.67)	(.49)	.75	.011
IC	.0056	.0063	.12	2.6	(1.33)	.18	(.74)	.15	.0065
RC	.014	.029	--	6.6	1.44	(.23)	1.1	.55	.109
RR	(.15)	.46	--	(17)	--	(.47)	.72	1.8	(.21)
IR	.0051	.075	.48	15	2.91	.24	3.2	.33	.013

( ) represents $r^2 < .4$

Table 4.4 (contd.)
Linear Regression Coefficients of Determination (r^2)

Station	TSS	TPT	TOTN	COD	BOD	Zn	Cu	Fe	Mn
IS1	.60	.95	.88	.67	.97	.85	.73	.77	.73
IS2	.99	.91	.49	.67	--	.56	.69	.57	.54
IS3	.74	.96	.92	.77	.98	.92	.73	.72	.42
IS4	.63	.85	.71	.86	.97	.70	.68	.92	.90
IS5	.63	.89	.89	.73	.96	.62	.63	.76	.93
RS1	.87	.89	--	.86	.97	.77	.56	.40	.87
RS3	.68	.66	--	.82	.84	.46	.49	.78	.63
II	.87	.40	.94	.63	.91	.23	.20	.93	.89
IC	.43	.78	.85	.73	.34	.67	.29	.47	.93
RC	.72	.96	--	.74	--	.23	.44	.77	.93
RR	.35	.57	--	.26	.99	.31	.50	.66	.39
IR	.74	.94	.96	.84	.98	.43	.96	.66	.87

5.0 COMPARISON WITH MARC NONPOINT SOURCE LOADING ESTIMATES

5.1 MARC 208 PLAN LOADING CALCULATIONS

The MARC 208 Plan used the Midwest Research Institute (MRI) "Nonpoint Calculator" to estimate nonpoint source loadings in the MARC area. Nonurbanized land uses and "urban open" land loads were calculated using the universal soil loss equation (USLE) for sediment and various enrichment factors for other chemical and heavy metal parameters. Pollutant loads for generalized urban residential, commercial, and industrial land uses were developed from statistical data from an EPA study based on street loadings. The NURP measured loadings were compared against the 208 Plan loading data in two ways: specific land use loads and loads from larger, mixed land use basins.

Kansas City Section 208 Plan pollutant loads per acre per year were calculated from four land use categories for seven parameter groups and reported in Product NP-10, "Stormwater Runoff Loads". These values were then compared against the monitoring data from the NURP land use sites (Table 5.1).

Results of Land Use Load Comparison

The 208 Plan loadings were generally higher than the NURP monitored loadings. Eleven of the twenty one comparisons (seven parameter groups for three land uses) showed 208 Plan loads that were at least twice as high as loads monitored at the NURP sites. The largest difference occurred with sediment (TSS) loads for an industrial land use. The 208 Plan's generalized industrial land use sediment load was calculated at 4400 lb/acre/yr compared to loading of 670 lbs/acre/yr monitored at the NURP industrial catchment (station II) in Lenexa. The commercial land use loads seemed to compare best between the 208 Plan and the NURP range of commercial area loads.

The comparison between these calculated and measured loads emphasizes the vast differences in loads that occur between similar land uses. Other site specific factors can confound prediction of loads by using the general land use factors. A basin wide loading calculation was performed to "average out" the wide range of monitored loads found at specific land use types. Loads calculated using 208 Plan data was compared to measured NURP loads for the Indian Creek watershed draining station IS5 (23,941 acres), station IS4 (1,375 acres) and the Rock Creek watershed of station RS3 (5,566 acres).

The calculated land use loads were applied to the land use distribution of these two basins. Land uses for these two watersheds were distributed to the four land use categories used in the 208 Plan (Table 5.2). Total annual loads per acre for these watersheds were then calculated using the percentage land use and the MARC 208 plan loading data. Finally, the MARC 208 Plan loading data was compared to the NURP monitored data (Table 5.3).

Table 5.1
MARC 208 Plan Calculated Land Use Loads Compared to NURP Monitored Land Use Loads
(lbs/acre/yr)

Pollutant	Source of Loading Data	Urban	Land Use Residential[1]	Commercial[2]	Industrial[3]
TSS	208 Plan	5200	2400	1100	4400
	NURP	---	64-2590	280-460	670
N	208 Plan	2.1	6.1	10.6	18.2
	NURP	-	2.6-3.8	.74-9.9	8.8
P	208 Plan	.55	1.6	1.8	4.1
	NURP	---	.65-5.2	.53-1.3	2.6
BOD	208 Plan	4.2	38	65	87
	NURP	---	5.0-35	9.9-13	56
Fe	208 Plan	13	51	26	108
	NURP	---	5.0-35	9.9-13	56
Mn-Ti	208 Plan	1.8	.97	.44	2.3
	NURP[4]	---	.18-3.8	.27-.56	.76-.87
Other	208 Plan[5]	.89	5.3	4.8	12.0
Metals	NURP[6]	---	< .75-1.4	.77-3.6	6.9-8.5

[1] NURP Monitored Loads from Stations RR, IR

[2] NURP Monitored Loads from Stations RC, IC

[3] NURP Monitored Loads from Station II

[4] Mn only

[5] Ba, Be, B, Cd, Ce, Cr, Co, Cu, Ga, La, Pb, Mo, Nd Ni, Nb, Sc, Sr, V, Yb, Y, Zn, Zr

[6] Cd, Cu, Pb, Zn only

Table 5.2
Large Basin Land Use

	Johnson Couny Indian Creek IS5	 IS4	Jackson County Rock Creek RS3
JC			
Vacant/Agricultural Public Recreational Private Recreational	30.8%	23.3%	21.2%
Single Family Multi-Family	58.1%	57%	72.5%
Commercial Educational Public Special	6.7%	14.7%	4.4%
Industrial	4.4%	0%	1.8%

Results of Large Basin Land Comparison

Generally, the comparison suggests that differences of more than an order of magnitude can occur by using simple loading models for larger basins. They seem to work best for highly urbanized smaller basins that are almost completely curbed and storm sewered. Even in the case of the best results, station IS4, a 300% overprediction of sediment loads occurred.

Table 5.3
MARC 208 Plan Calculated vs. NURP Monitored Nonpoint Source Loads
(lb/acre/yr)

	TSS	N	P	BOD	Fe	MN + TI	Other Metals
IS5							
208 Plan	3300	5.7	1.4	32.	40	1.2	4.2[2]
NURP	1300	11.0	2.5	32.	155	4.7[1]	2.5-3.7[3]
RS3							
208 Plan	3000	5.7	1.4	33.	43	1.1	4.5[2]
NURP	5000	6.5	4.2	27.	120	6.2[1]	2.6-3.1[3]
IS4							
208 Plan	2700	5.5	1.3	32.	36	1.0	3.9
NURP	950	6.6	1.2	23.	46	1.5[1]	1.4-2.6

[1] Mn only

[2] Ba, Be, B, Cd, Ce, Cr, Co, Ga, La, Pb, Mo, Nd, Ni, Nb, Sc, Sr, V, Yb, Y, Zn, Zr

[3] Cd, Cu, Pb, Zn only

TSS

The 208 Plan method overpredicted the Indian Creek loads at IS4 and IS5 by over 250%. In the steep, eroding Rock Creek basin the 208 Plan underpredicted loads by 40%, a much closer margin. The overprediction of the Indian Creek loads suggested that the other parameter's loads would be overpredicted as enrichment factors were utilized to develop these other loading functions. The consistant overprediction was not observed, suggesting that the 208 Plan calculation's enrichment factors of the other parameters are not representative of actual delivery ratios.

Nitrogen

The 208 Plan was close to measured Rock Creek (RS3) loads and the Indian Creek IS4 loads and underpredicted the IS5 loads. The high measured IS5 NURP load may be caused by some treatment plant settling and not reflect actual nonpoint source pollutants.

Phosphorus

The IS4 measured load was predicted closely by the 208 loadings. The IS5 and RS3 stations were underpredicted by a factor of 44% and 66% respectively.

BOD

The predicted values were very close for all but IS4, where the 208 Plan overpredicted loads by about 50%.

Iron

Station IS4 predicted and measured loads were relatively close; the other two stations had predicted loads about 70% lower than actual loads.

Manganese and Titanium
Other Metals

Although these 208 Plan categories could not be compared directly with measured loads, this analysis did indicate that manganese loads were underpredicted for the larger basins (RS3 and IS5). The other metals category predicted loading was close to but higher than the four representative metals monitored by the NURP study.

Conclusion

Large loading variations were found in the NURP study for both small specific land use catchments and for larger mixed land use basins. The 208 Plan loadings were generally higher than the highest annual loads monitored from the NURP land uses. When the 208 loads were applied to a larger mixed land use watershed, they generally underpredicted everything but sediment loads from the two different larger watersheds and were in good agreement (except for sediment) for a smaller basin that was mostly curbed and storm sewered.

The sediment (TSS) load predictions, which were used to estimate the other parameter loads, were both above and below measured values. The steep, eroding Rock Creek watershed load was underpredicted while the loads from the well maintained urban areas of Johnson County were overpredicted. The other parameters were not consistantly overpredicted or underpredicted along with the sediment load prediction. This suggests the enrichment factors that were used to calculate the other parameters from the sediment land are not consistant load predictors and vary from basin to basin.

This analysis suggested the 208 Plan loads were generally two or three times higher than measured loads at specific land use sites. For larger, mixed basins the predicted loads usually ranged from 25% to 184% of the measured loads and were usually smaller.

The smaller, well maintained basin (IS4) produced the best comparisons between calculated and measured loads for all parameters except sediment (TSS). For TSS, the steeper, eroding basin (RS3) was modeled best. The nutrient parameters (N and P) predicted loads ranged from 33% to 88% of the measured load, and iron and manganese were also underpredicted. BOD loads were relatively close.

5.2 MARC MODEL EROSION CONTROL ORDINANCE

The MARC Model Erosion Control Ordinance is designed to implement a five ton/acre/year erosion performance standard for all developing non-agricultural areas greater than one acre in size. The ordinance was designed with these goals:

1. To substantially reduce sedimentation and erosion damage.
2. To preserve land values.
3. To establish reasonable standards of design and procedures for development.
4. To prevent pollution of water courses by sediment.
5. To minimize the danger of flood loss.

As of 1982 only Clay County has passed elements of this ordinance to control erosion. The Clay County version requires the plat approval process include soil and conservation service review of the development plan. No performance standard was incorporated into the ordinance.

The NURP data showed a wide range of sediment loadings, from .03 to 2.5 tons/acre/yr for the different watersheds. The highest sediment loads occurred in the Rock Creek watershed, where steep basin slopes, channel slopes, combined with swale drainage has created areas with high erosion rates.

The NURP data was used to compare average pollutant loads from specific land use types to the loads actually found in downstream areas. A significant additional amount of pollutants were found in the downstream areas, indicating that high loadings were being produced by land uses other than the typical residential, commercial, and industrial areas. This suggess that if small "hazardous nonpoint source zones" such as gullies, channel erosion, pockets of agriculture, and construction can be controlled, significant reduction in annual nonpoint loads can be made. Section 3.3.2 describes the potential effect of an erosion control ordinance aimed at these areas.

6.0 BENTHIC MONITORING PROGRAM

The Johnson County Unified Wastewater District has monitored benthic macroinvertebrate populations for three and a half years at 10 locations on Indian Creek. The goals of this data collection in relation to the NURP project were to:

1. Assess the water quality of Indian Creek as reflected by pollutant effects on the benthos.

2. Assess the effects of the point source wastewater treatment plant discharge versus the effects of nonpoint source urban runoff on the benthos.

3. Determine if a pollutant tolerant type of benthic community develops as the drainage basin becomes urbanized.

During the benthic collection period, Indian Creek received a constant flow of secondary effluent from the Blackbob Wastewater Treatment Plant in Olathe in addition to periodic pulses of nonpoint source pollutants from urban runoff in the basin. Two additional significant events occurred: A major oil spill in the Spring of 1979, and the discharge of low quality effluent from the Blackbob plant due to an overloaded system during the summer of 1980. Although these impacts tend to confound the data, and made an assessment of the relative effects of urban runoff difficult, several general trends were detected.

1. While the wastewater treatment plant in Olathe was a major influence on Indian Creek above station IS1 in 1978, the healthy benthic composition at this station indicated that the creek had recovered from the wastewater impact by this point.

2. Below station IS1, a marked decrease in total numbers of organisms was seen, and to a lesser extent in total taxa, corresponding to both increased urbanization and drainage from an industrialized and urbanized tributary of Indian Creek.

3. In 1978, by station IS5, a large increase in the total numbers of two dominant genera, caddisflies and riffle beetles, was seen. The high species diversity that had occurred at IS1 was not present. This may have been related to increased food availability due to nutrients present in urban runoff.

4. Throughout the course of the study, the benthic community at IS1 or below in the urbanized reaches did not return to its 1978 composition; the community that did develop shifted to a pollutant tolerant assemblage dominated by black flies and midges.

5. This shift in benthic community composition corresponds to increasing urbanization of the Indian Creek basin and discharge of lower quality effluent and indicates lower water quality as reflected by lower species diversity, lower biomass, lower numbers of taxa, and reduction in the dominance of the native benthic community.

The benthic macroinvertebrate community in Indian Creek appears to be in a state of transition, responding to two influences. One is the wastewater effluent, and the other is urban runoff. The high organic loading from the treatment plant disrupts the benthic community in the downstream area but recovery occurs at or around station IS1. A sustained recovery downstream of this site is not observed, a continued degradation is seen with an overall shift in the makeup of the community. Species diversities and number of taxa are reduced. Total population density fluctuates and is reduced overall downstream, with numbers of organisms remain relatively high, but still less than numbers observed in 1978 at the beginning of data collection.

This suggests that a toxic impact from urban runoff is resulting in the exclusion of some taxa in the downstream reach. Since total numbers remain relatively high, the organisms that do survive are probably benefiting from the higher nutrient loads from the effluent and reach higher numbers than they would in the absence of these high concentrations.

6.1 BENTHIC SAMPLING METHODOLOGY

Data were collected quantitatively and qualitatively as described below:

Date	Method
Fall 1978	Quantitative
Summer 1979	Quantitative
Fall 1979	Quantitative
Summer 1980	Qualitative
Spring 1981	Qualitative
Summer 1981	Qualitative
Fall 1981	Qualitative
Spring 1982	Qualitative

6.1.1 QUANTITATIVE SAMPLING

A Surber Square Foot Sampler was used to collect random samples at each riffle site. Replicate samples were collected in most cases. Samples were sorted and counted in the laboratory resulting in a complete inventory of the sampled community. For a complete description of the method, see Biological Field and Laboratory Methods, EPA-670/4-73-001, Macroinvertebrate Chapter.

6.1.2 QUALITATIVE SAMPLING

Qualitative sampling emphasis was on obtaining a complete species inventory rather than an exact determination of numbers per species. Riffles were divided into sections that could be inventoried within a 10 minute time period. Two samplers spent equal time in the divided sections and examined all habitats with the aid of small drift nets, and the types and numbers of individual taxa were noted. At the end of the 10 minute period, each organism was assigned to a class representing an estimate of the numbers seen. These classes and their ranges were:

Class	Number of Individuals Per Class
1	0
2	1-10
3	10-50
4	50-100
5	100-500
6	> 500

Where applicable, (+) or (-) designations were assigned to indicate whether observed numbers were closer to one end or the other of a class.

Organisms were identified to the lowest taxonomic group possible without the aid of a microscope. Through previous quantitative sampling, a good basis for knowing what taxa to expect to occur in the creek was formed. An example table of field results is shown below:

Organism	Riffle Section		
	1	2	3
Mayflies	2	2-	3
Caenis	1	2	2+
Baetis	1	2	2+
Stenonema	3	3	4
Damselfly/Dragonfly			
Argia	2	3	2-

Additional field data noting water clarity, algal growth, substrate type, etc. were included for each site.

6.2 DATA STANDARDIZATION

When the benthic sampling effort was initiated by the Johnson County Unified Wastewater Districts in 1978, quantitative sampling was the chosen method due to the relative ease and acceptability of applying standard statistical tests to the data. When the decision was made to include benthic sampling in the NURP program, the number of sites was expanded within the NURP study area. Because of the time involved in quantitative analysis, the qualitative sampling strategy described above was devised and implemented.

For analysis of these data, it was desirable to have a continuous record from 1978-1982. Because sampling methodology was changed, the following methodology was used to generate a uniform data base to be used for all of the benthic data analyses.

6.2.1 QUALITATIVE DATA

The class designations were expanded from a total of seven classes to a total of 16 classes. Within the expanded classes, numbers of organisms in each were assigned. Class expansion was done to make the analyses more sensitive to relative changes in numbers of an organism and between different organisms. It should be noted that the expanded classes are synthetic and correspond to, but are not the same as, the ones used during field sampling.

In order to expand the classes, the (+) and (-) designations were used. Where the original classes include the range from 0->500 organisms, the expanded classes range from 0->900 organisms. An attempt was made to set the range of numbers in a class wide enough to be detectable in the field but narrow enough to be sensitive to changes in abundance.

To make the class value designations more accurately reflect their magnitude in relation to other classes, all values were expressed as a percentage of 900 which was the highest number used in the expanded class ranges. The class expansion maneuver resulted in increased sensitivity both in terms of actual abundance and relative abundance. The new classes are presented below·

Old Class Value	Old # of Organisms per class	New Class Value	New # of Organisms per class
1	0	0	0
2-		.22	1-3
2	1-10	.61	4-7
2+		1.0	8-10
3-		1.7	11-20
3	10-50	3.3	21-40
3+		5.0	41-50
4-		6.7	51-70
4	50-100	8.9	71-90
4+		12.0	91-120
5-		16.0	121-160
5	100-500	20.0	161-200
5+		33.0	201-400
6-		61.0	401-700
6	>500	89.0	701-900
6+		100.0	>900

The original qualitative data were transformed to reflect the expanded classes by substituting the new class value for the old one as shown below:

Organism	Old Riffle Section			Expanded Riffle Section		
	1	2	3	1	2	3
Mayflies						
Caenis	2	2-	3	.61	.22	3.3
Baetis	1	2	2+	0	.61	1.0
Stenonema	3	3	4	3.3	3.3	4

Finally, the data were condensed by averaging class values for each organism, resulting in one number per organism per sample. This is the standardized number as shown below:

	Expanded Raw Data			Standardized Number
Caenis	.61	.22	3.3	1.38
Baetis	0	.61	1.0	0.54
Stenonema	3.3	3.3	4	3.53

6.2.2 QUANTITATIVE DATA

The same procedure was used to transform the quantitative data. Numbers recorded on laboratory data sheets were grouped and assigned to corresponding class value. An example follows:

	Actual #	Class	Class Value
Caenis	3	1-3	.22
Baetis	12	10-30	1.7
Stenonema	82	70-90	8.9

In order to confirm that this data transformation step did not alter the information contained in the raw data, the Shannon-Wiener Diversity Index was applied to the new class values and compared to diversities obtained for the original data. This was done on a wide variety of data bases, ranging from Indian Creek data to data from literature on North Carolina streams.

For all but one case, transformed quantitative data diversity indexes corresponded favorably with raw data diversity indexes. This indicates that the transformation did not substantially affect the information contained in the raw data.

This method was applied to all of the data, and produced a uniform data base that reflected the relative abundance of organisms in a riffle and allowed a quantitative evaluation of the diversity of that community.

6.3 SITE DESCRIPTIONS

Indian Creek originates in central Johnson County and flows northeasterly through Olathe, Overland Park, and Leawood, Kansas, draining about 40 square miles of the County. With slopes ranging from mild to moderate, the stream bottom substrate in riffle areas varies from limestone bedrock to limestone and sandstone rubble, silt and gravel. The rapidly flowing shallow riffle areas are separated by long deep pools.

Riffles were sampled instead of pools because they provide a more productive habitat for benthic organisms. Ten sites were chosen on the basis of location and access, and spaced to cover the entire reach of the creek corresponding to the NURP study area. Site 1 was the furthest upstream, above the treatment plant discharge and site 10 the furthest downstream. Site 2 was just below the outfall of the Blackbob Wastewater Treatment Plant. Sites 3 and 4 were downstream of this; site 5 was the same as IS1. Site 6 was downstream from IS1, in the Corporate Woods Office Park, and site 7 corresponded to IS3. Site 8 was downstream of site 7 and site 9 correponded to IS5. Site 10 was just downstream of the lower Indian Creek wastewater treatment plant outfall. Figure 6.1 presents the location of the sites and site characteristics are summarized in Table 6.1.

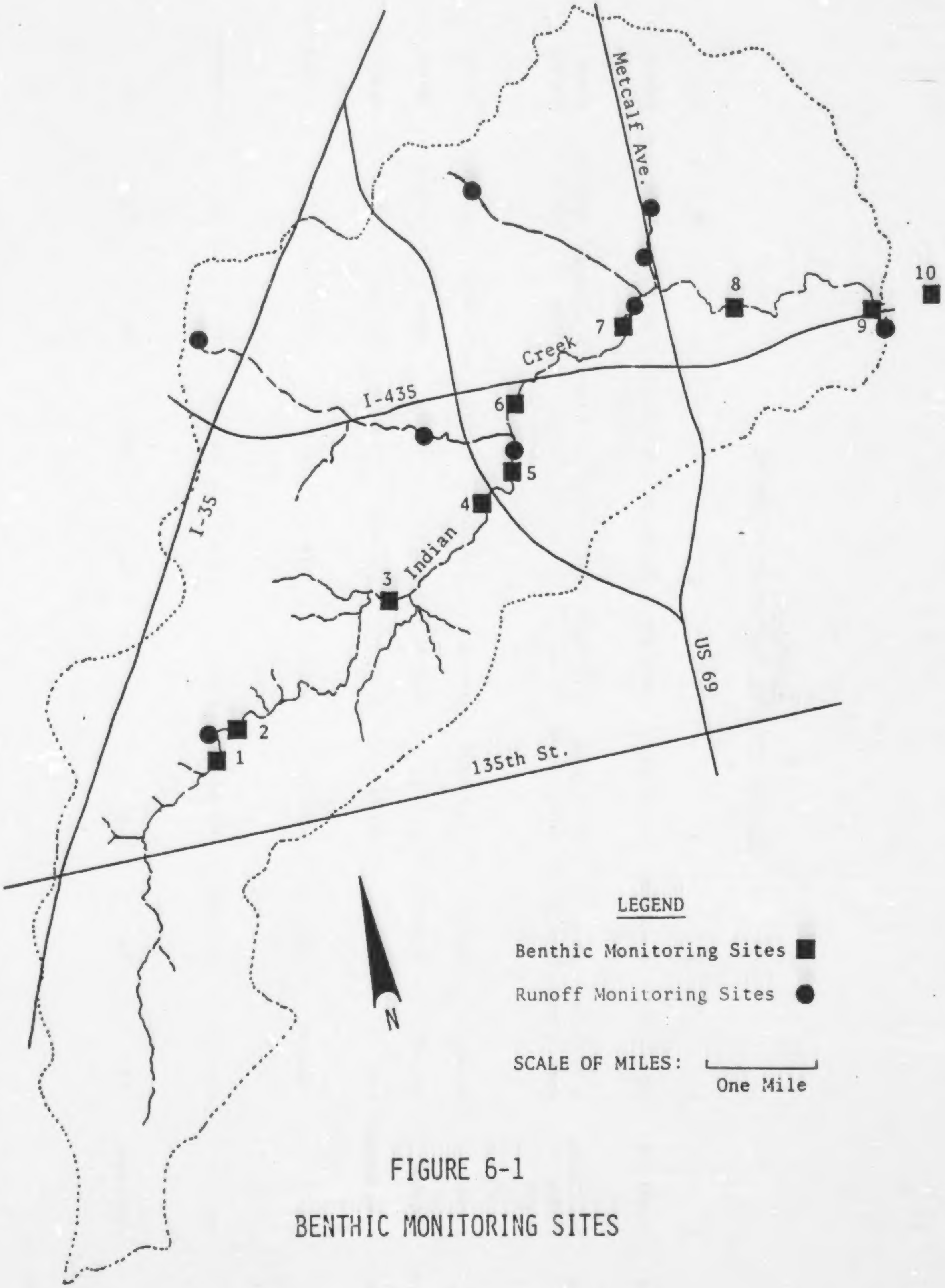

Metcalf Ave.
10
8
7
9
Creek
I-435
6
5
4
I-35
Indian
3
US 69
2
1
135th St.
N
LEGEND
Benthic Monitoring Sites ■
Runoff Monitoring Sites ●
SCALE OF MILES:
One Mile

FIGURE 6-1

BENTHIC MONITORING SITES

Table 6.1
Benthic Sampling Stations Descriptions

	SITE									
	1	2	3	4	5	6	7	8	9	10
Substrate type	limestone	limestone	limestone	limestone	limestone	limestone	sandstone, limestone	limestone	limestone	limestone
Substrate size	5-18"slabs rubble w/silt	5-10"rocks some gravel	loose sand and gravel	3-12"rocks some gravel	3-12"rocks gravel bedrock	5-12"rocks	sandstone slabs, limestone gravel	5-10"rocks slabs	gravel, slabs	slabs, gravel
Sponges	common	absent	absent	occasional	common	common	common	common	common	absent
Bryozoans	common	absent	absent	absent	absent	absent	absent	absent	absent	absent
Attached algae	occasional	rare	rare	occasional	common	common	common	common	comon	common
Septic conditions observed	no	common	common	occasional	rare	rare	rare	rare	no	occasional
Sewage fungus present	no	common	common	occasional	rare	rare	rare	no	no	common
Stream miles from Olathe STP effluent discharge	upstream	.31	3.6	5.6	6.6	7.1	9.0	10	12	15
Location	Blackbob Rd & Indian Creek Pkwy Olathe, KS	Blackbob Rd & 127th St. Olathe	119th & Quivira Rd Overland Park, KS	Alternate 69 Hwy Bridge	IS1, College Blvd.	Corporate Woods Office Park	IS3, 103rd & Marty	Indian Creek Pkwy & Lamar Ave.	IS5, Mission Road Leawood, KS	Leawood City Park

6.4 CHARACTERIZATION OF THE BASELINE BENTHIC COMMUNITY

Throughout this analysis, the Fall 1978 collection was used as baseline data to evaluate the benthic community. The fall 1978 collection was made before the oil spill or the discharge of the enriched effluent and represents the period in which the Indian Creek basin was much less urbanized than it is at present. The pooled data set covers the stream reach from Site 5 through Site 10, beginning about 6 miles below the outfall of the Olathe treatment plant, running through a moderately urbanized area, and ending below the outfall of the lower Indian Creek wastewater treatment plant. Thus the benthic community existing during the Fall of 1978 represents one that developed in response to the instream, physiochemical environment and to the steady discharge of secondary effluent from the Blackbob Treatment Plant with the secondary impact of urban runoff.

The organisms found in the pooled data set (all sites from Fall 1978) are presented in Table 6.2.

Table 6.2
Indian Creek
Taxonomic Groups and Percent
of Total Community-Fall 1978

Taxa	% of Total
Caenis	0.40
Baetis	3.4
Stenonema/Stenacron	5.1
Cheumatopsyche	38
Hydropsyche	8.4
Hydroptila	0.20
Stenelmis	13
Tropisternus	0.03
Bloodworm	0.71
Nonbloodworm	21
Simuliidae	0.52
Argia	0.28
Gerridae	0.03
Velliidae	0.03
Mooreobdella	0.30
Physa	4
Helisoma	0.93
Ferrissia	0.20
Sphaeriidae	2.0
Hyalella	0.03
Planaria	0.06
Tubificidae	1.5
Eristalis	0.06
Lepidoptera	*
Chaoborus	*

* = < .01%

This baseline community was compared with a community found in another Johnson County stream, Cedar Creek, that has similar geographic and physiochemical characteristics but receives only a minor amount of effluent in one tributary and is urbanized only slightly (Table 6.3). Indian Creek benthic data were also compared to Mill Creek, a stream impacted by wastewater discharge to a large degree and urban runoff only slightly (Table 6.4). Collections from both of these creeks were made through several seasons from winter 1977 to late summer of 1978. Thus, the general timing of the sampling of the three creeks was the same; however, Indian Creek data reflect only one collection at several stations while Mill and Cedar creek data are a composite of several stations through several seasons.

Natural, unimpacted streams in the Johnson County geographic region are characterized by a stonefly, mayfly, caddisfly, riffle beetle indicator community with these groups making up a large percentage of the total and the remainder distributed throughout a number of additional taxa typically including midges, flies and snails.

Table 6.5 summarizes taxonomic information, Shannon-Wiener Diversity indices, and percent composition of the indicator community for the three streams. Indian Creek fell between the two streams with respect to these parameters. The total number of different taxa found in Indian Creek (23) was closer to Mill Creek (22) than to Cedar Creek (38), yet the species diversity in Indian Creek (2.96) was closer to Cedar Creek (2.60) than to Mill Creek (2.11). Sixty three percent of the taxa in Indian Creek were in the indicator community, while Cedar Creek had 32% and Mill Creek only 10%. However when comparing indicator taxa between Indian Creek and Cedar Creek, there is a conspicuous lack of one whole group, the stoneflies, in both Indian and Mill Creeks, in addition, certain genera of caddisflies found in Cedar Creek were not present in Indian Creek.

Table 6.3
Cedar Creek
Taxonomic Groups and Percent of Total Community 1978

Taxa	% of Total
Allocapnia	0.76
Amnicola	0.01
Argia	0.08
Baetis	2.9
Berosus	*
Caenis	3.6
Ceraclea	0.04
Chaoborus	*
Cheumatopsyche	4.6
Chimarra	0.36
Chironomidae	50
Ferrissia	*
Hemerodromia	0.12
Helisoma	0.01
Hirudinea	0.07
Hyalella	0.07
Hydropsyche	0.02
Isoperla	0.25
Lirceus	0.14
Microvelia	0.07
Nematoda	*
Neoperla	0.03
Oligochaeta	5.2
Orconectes	0.91
Perlesta	0.2
Physa	0.31
Planaria	0.63
Polycentropus	*
Rhagovelia	*
Ryacophila	0.02
Sialis	0.02
Simulium	7.1
Sphaerium	0.26
Stenacron	2.5
Stenelmis	18.4
Stenonema	1.3

* = <.01%

Table 6.4
Mill Creek
Taxonomic Groups and Percent of Total Community - 1978

Taxa	% of Total
Baetis	5.3
Caenis	0.13
Cheumatopsyche	2.8
Chironomidae	30
Gyralus	*
Hemerodromia	0.06
Hirudinea	0.08
Hyalella	0.05
Hydroptila	*
Lirceus	*
Micracantha	0.01
Oligochaeta	19
Orconectes	0.07
Physa	0.37
Planaria	*
Psychoda	0.08
Simulium	40
Sphaerium	0.21
Stenacron	0.53
Stenelmis	1.4
Stenonema	*

* = < .01%

Table 6.5
Taxonomic Data, Species Diversities (d) and Indicator Community Percentages of Indian, Cedar and Mill Creek

	Indian	Cedar	Mill
Number of Different Taxa	23	38	22
Species Diversity (d)	2.96	2.60	2.11
Indicator Community Percentage	63	32	10
Number of Taxa in Indicator Community	7	10	6

These data indicate that Indian Creek during the Fall of 1978 was somewhat impacted by the wastewater discharge as indicated by the reduced number of taxa when compared to the relatively wastewater impact free Cedar Creek. It bears similarity to the organically polluted Mill Creek in that a whole taxonomic group, the stoneflies, was absent from both, reflecting their sensitivity to high organic loads. Indian Creek at that time, however, appeared able to support a large portion of the endemic community, though there was a reduction in total number of taxa and a shift of taxa to the more organic tolerant forms in the lower reaches of the stream.

6.5 DATA SET POOLED 1978-1982

The total taxa found in Indian Creek by site from Fall 1978- Spring 1982 and the number of times the taxa was found, the total standardized percent of the total for each taxa, and the mean standardization number of individuals in the taxa are presented in Table 6.6. At Site 1, 20 taxa occurred. This number was reduced to 7 at Site 2, just downstream of the effluent outfall. The number of taxa gradually increases through Site 4, and at Site 5 there were more taxa present than at Site 1. This number fell slightly from Sites 6-8 and increased again at Site 9. At Site 10 below the second treatment plant outfall, the number of taxa was again reduced. This trend corresponds to observations made in the Fall 1978 data that from Site 5 to Site 8, the benthic community is disturbed by some factor other than the wastewater effluent. In this previous report, it was noted that recovery from the treatment plant effluent occurred by Site 5 as indicated by the community composition at that site. These data support that observation. At Site 9, both studies show the numbers and taxa to increase above that observed at the other sites, then to fall again at Site 10.

Table 6.6
Total Species List
All Collections Pooled by Site

Organism	1	2	3	4	5	6	7	8	9	10
Caenis	x			x	x	x	x	x	x	x
Baetis	x			x	x	x	x	x	x	x
Stenonema	x	x	x	x	x	x	x	x	x	x
Cheumatopsyche	x		x	x	x	x	x	x	x	x
Hydropsyche					x					
Hydroptila					x		x	x	x	
Stenelmis	x	x	x	x	x	x	x	x	x	x
Tropisternus	x		x	x				x		
Bloodworm	x	x	x	x	x	x	x	x	x	x
Nonbloodworm	x	x	x	x	x	x	x	x	x	x
Simuliidae	x		x	x	x	x	x	x	x	x
Argia	x		x	x	x	x	x	x	x	x
Collembola			x		x	x			x	x
Gerridae									x	
Velliidae						x			x	
Saldidae	x				x	x			x	
Mooreobdella			x	x	x	x	x	x	x	x
Erpobdella				x	x			x		
Placobdella	x			x	x		x		x	x
Physa	x	x	x	x	x	x	x	x	x	x
Gyralus					x					
Helisoma	x		x	x	x	x	x	x	x	x
Ferrissia	x				x	x	x	x	x	x
Sphaeriidae	x				x	x	x	x	x	x
Orconectes	x		x	x	x	x	x	x	x	x
Lirceus	x		x	x	x	x	x	x	x	x
Hyalella			x	x	x	x	x	x	x	x
Planaria	x						x		x	
Tubificidae	x	x	x	x	x	x	x	x	x	x
Eristalis		x			x		x		x	
Asellus			x							
Lymnaea							x		x	
Lepidoptera					x					
Chaoborus					x					
Hemerodromia					x					
Tridactylus					x					
Gelastocondae					x					
NUMBER TAXA	20	7	14	19	31	21	23	21	27	20

x = < .01%

The data is pooled by major group in three ways in Table 6.7. The 1978 pooling represents the baseline community from Fall 1978. The second column represents the total data set (1978-1982) pooled from sites 5-10 only, corresponding to the sites included in the Fall 1978 data set. The last column represents all data (1978-1982) from all sites. These data show a shift in the makeup of the community during the three and a half year sample period. The indicator community declined by approximately a factor of 2 from sites 5-10 and slightly more overall. Bloodworms have increased from sites 5-10 over the 1978 levels, but the pooled data from all sites show that most of the bloodworms still occur between sites 2 and 4, corresponding to the effluent impact zone. The nonbloodworm group has increased by 5-8%, and they make up a larger percent of the total from sites 5-10 overall than they did in 1978. The largest increase was seen in the black fly population with the miscellaneous community increasing by a factor of 1.5 from sites 5-10 and a factor of 2 overall.

Previous data established that benthic community recovery from the effluent generally occurred by site 5. Given no additional disturbance, the stream should support a similar community downstream as it did in 1978. These data show that a more pollutant tolerant type of assemblage has developed in the creek from 1978 to 1982, corresponding to rapid urbanization of that part of the basin.

Table 6.7
Major Groups (% of Total) for Fall 1978
and the Pooled Data Sets

	Fall 1978	Sites 5-10 Pooled	All Data Pooled
Mayfly, Caddisfly, Riffle Beetle	63	32	27
Bloodworms	0.78	3	8.6
Nonbloodworms	22	30	27
Black fly	0.52	14	9.8
Miscellaneous	14	21	28

6.6 SINGLE NUMBER SUMMARIES BY SAMPLE COLLECTION

The species diversity, standardized total number of individuals and number of different taxa found during each collection period are presented in Table 6.8. These data examine changes through time but mask downstream effects.

Both pools of data reflect a general decline in number of taxa in the stream since 1978, except for during the summer of 1980, which was probably related to the enriched environment caused by discharge of poor quality effluent. Both data sets also reflect a general decline in total biomass since 1978.

The principle observations from these data are that the creek was fairly healthy in the Fall 1978 sample. Although the Spring 1979 oil spill caused drastic reductions in total numbers, taxa, and species diversity the recovery appeared to have been underway in Fall 1979. The impact from poor effluent quality in the Summer 1980 sample resulted in higher numbers, more taxa, and a higher diversity, and was probably caused by the enriched environment. With the removal of this disturbance in the remaining samples, total numbers and number of taxa are consistently lower than Fall 1978. The diversity is lower for all but one sample in the entire data set and always lower when sites 5-10 are pooled separately.

These data support the conclusion of the pooled (1978-1982) data set that the water quality in Indian Creek as declined since 1978 as reflected by the benthic organisms.

Table 6.8
Species Diversity, Standardized Total Number of Individuals, and Number of Different Taxa by Collection Date

	Fall 78	Summer 79	Fall 79	Summer 80	Spring 81	Summer 81	Fall 81	Spring 82
Pooled from Site 5-10:								
# of taxa	23	15	18	23	17	16	19	15
Std. Total Specimens	730	383	968	331	547	332	509	103
d	2.96	1.75	2.71	2.75	1.90	1.34	2.94	1.96
All data Pooled:								
# of taxa	23	15	18	27	18	17	19	15
Std. Total Specimens	730	383	968	688	695	488	659	252
d	2.96	1.75	2.71	3.15	2.08	1.62	3.06	2.14

6.7 SINGLE NUMBER SUMMARIES BY SITE

The data pooled according to site for all sampling and during the three and a half years of monitoring is presented in Table 6.9. This table presents downstream effects from the point source through the urbanized area and presents an analysis of benthic community recovery.

The downstream benthic recovery from the effluent impact is observed at Site 5 with a decline downstream of Site 5 to Site 9 for all parameters. The total number of specimens and mean number of specimens and the total number of different taxa peaked at Site 5. The upper range of taxa found at any one time at Site 5 was exceeded only by Site 9. The mean number of taxa peaked at Site 4 and then stayed fairly constant until Site 9. The upper range of the diversity also peaked at Site 5, then declined until Site 9. The mean diversity was highest at Site 6.

This data set shows a baseline community at Site 1 that is severely impacted by the effluent at Site 2 where parametric indicators consistently decline. These make a slow recovery and peak at Site 5. After Site 5 a decline occurs again until Site 9 which usually shows fairly good indicators. When viewed in this manner, the data again indicate an impact not related to effluent discharges on the benthos in the urbanized stream section.

Table 6.9
Station Summaries By Site
All Data (1978-1982)

	Site									
	1	2	3	4	5	6	7	8	9	10
# of Collections	5	5	4	4	8	7	8	7	8	8
Standardized Total Specimens	86	428	257	327	1077	366	448	342	639	931
Mean # Specimens	17	86	64	82	135	52	56	49	91	116
Total Different Taxa	20	7	14	19	25	21	23	21	27	20
Range of Taxa	8-13	2-4	4-11	10-15	5-17	8-15	6-16	5-14	10-18	6-14
Mean Taxa	11	3	8	12	11	11	10	10	12	11
Range of d	1.03-2.84	.07-1.01	.96-1.50	.8-2.14	.92-2.68	1.48-2.58	1.26-2.49	1.47-2.33	.86-2.77	1.06-2.26
Mean d	1.74	.36	1.25	1.49	1.88	2.00	1.95	1.87	2.02	1.73

6.8 SENSITIVITY ANALYSIS

6.8.1 TOLERANCE TO ORGANIC POLLUTION

Each benthic organism was assigned a classification of tolerant, faculative or intolerant, defined as follows:

Tolerant -	Organisms frequently associated with gross organic contamination and generally capable of thriving under low oxygen conditions.
Faculative -	Organisms having a wide range of tolerance and frequently associated with moderate levels of organic contamination.
Intolerant -	Organisms that are not found associated with even moderate levels of organic contaminants and generally intolerant of even moderate reductions in dissolved oxygen.

Since tolerant organisms may be found in both clean and stressed waters, the only positive evidence of clean water that can be presented from this evaluation is the presence of intolerant organisms.

In this analysis weighted total numbers of organisms were used to derive percentages. Thus, the final percentages of the community assigned to each classification reflect both taxa and relative abundance of each taxa.

Table 6.10 presents the percent of the benthic community in Indian Creek that was tolerant, facultative and intolerant by year, with all site data pooled. This was an evaluation of the community structure through time (temporal) and disregarded upstream to downstream (spatial) effects.

The most significant observation was that intolerant organisms made up 5% of the total community in the creek in the Fall 1978 sample. After this time, they disappeared or were negligible. This indicates that until Fall 1978, the creek was capable of supporting organisms that are intolerant to low dissolved oxygen or moderate loads of organic pollution.

Table 6.11 presents the data partitioned by site and collection date. In Fall of 1978, 24% of the community at Site 5 was intolerant, corresponding to previous data suggesting that recovery from the Blackbob Treatment Plant effluent had occurred by Site 5. Proceeding downstream, the contribution of intolerant organisms drops to less than 1%, and they were absent at sites 9 and 10. In the Summer of 1979 data, after the oilspill, only 0.1% of the community at site 5 was intolerant; and the remaining organisms were more evenly distributed between the tolerant and faculative groups than in the Fall of 1978. Recovery from the oil spill by Fall of 1979 was reflected in the presence of a few intolerant organisms in the stream and the decreased percentages of the tolerant group.

These three sample collections, when viewed in terms of the tolerance of the organisms, support the conclusions reached with the single number summaries: In the Fall of 1978, recovery from the effluent occurred by Site 5 with subsequent exclusion of some organisms downstream; disruption of the community was caused by the oil spill in Summer of 1979; a recovery from the spill was taking place by Fall 1979.

The Summer 1980 data reflect the impact of the effluent as seen in the higher percentages of tolerant organisms through Site 6, indicating that the recovery zone was pushed further downstream. The remaining data indicate a fluctuating environment, and no consistent trends fall out. Partitioning of the data both by site and date tends to obscure any generalizations.

One whole group of organisms, the stoneflies, was absent from every site in Indian Creek. Stoneflies are classified as intolerant, and the fact that they never occurred during the sample period is indicative of at least a moderately polluted stream.

Table 6.10
SENSITIVITY ANALYSIS

Percent of Community as Tolerant
Faculative and Intolerant by Year
with all Data Pooled

Date	Tolerant		Facultative		Intolerant	
	All Sites Pooled	Sites 5-10 Pooled	All Sites Pooled	Sites 5-10 Pooled	All Sites Pooled	Sites 5-10 Pooled
Fall 1978	--	13	--	82	--	5
Summer 1979	--	42	--	58	--	0
Fall 1979	--	13	--	87	--	0
Summer 1980	43	27	57	73	0	0
Spring 1981	32	25	68	75	0	0
Summer 1981	23	3	77	97	0	0
Fall 1981	40	38	60	62	0	0
Spring 1982	30	18	70	82	0	0

Table 6.11
Sensitivity Analysis
Percent of Community as Tolerant, Facultative and Intolerant
By Site and Date

Date		Site 1	2	3	4	5	6	7	8	9	10
Fall 78	T					6		4	5	8	43
	F					70		95.6	94.8	92	57
	I					24		0.4	0.2		
Summer 79	T					55	41	30	67	21	36
	F					44.9	59	70	33	79	64
	I					0.1					
Fall 79	T					27	0.6	5.9	5.9	5	34
	F					72.8	99.4	94	94	95	66
	I					0.2		0.1	0.1		
Summer 80	T	11	100	88	68	71	14	14	8	3	49
	F	89		12	32	29	86	83	92	97	51
	I							3			
Spring 81	T	52	99.1	17	3	22	11	38	24	8	47
	F	48	0.90	83	97	78	89	62	76	92	53
Summer 81	T	5	94		92	1	5	6	1	1	6
	F	95	6		8	99	95	94	99	99	94
Fall 81	T	21	99.9	13		35	55	46	13	31	47
	F	79	0.1	87		65	45	54	87	69	53
Spring 82	T	46	100	10	19	17	6	3	20	4	57
	F	54		90	81	83	94	97	80	96	43

T = tolerant
F = facultative
I = intolerant

6.9 DOMINANCE OF THE INDICATOR COMMUNITY

The indicator community in Indian Creek is the caddisfly, mayfly, riffle beetle association. Table 6.12 presents a breakdown of the benthic community according to major group by collection date with all sites pooled, and with sites 5-10 only pooled.

Table 6.12
Indicator Community Pooled
% of Total (All Sites)

	MF, CF, RB	NBW	BW	BF	MISC
Fall 78	64	19	1	0	16
Summer 79	13	43	2	0	42
Fall 79	30	24	4	30	12
Summer 80	30	10	18	13	29
Spring 81	5	40	13	21	21
Summer 81	45	27	24	1	3
Fall 81	20	5	12	30	33
Spring 82	6	39	6	24	25

MC, CF, RB = Mayfly, Caddisfly, Riffle beetle
NBW = Nonbloodworm
BW = Bloodworm
BF = Black fly
MISC = Miscellaneous groups

Table 6.12 (cont.)
Indicator Community Pooled
% of Total (Sites 5-10)

	MF, CF, RB	NBW	BW	BF	MISC
Fall 78	64	19	1	0	16
Summer 79	13	43	2	0	42
Fall 79	30	24	4	30	12
Summer 80	62	9	5	10	14
Spring 81	7	52	2	12	27
Summer 81	53	42	1	1	4
Fall 81	18	6	1	33	42
Spring 82	7	49	8	25	11

These data indicate a shift in the makeup of the community especially when comparing the site 5-10 pooled data set. A decline (even when accounting for seasonal effects) in the dominance of the indicator community has occurred since 1978. A concurrent increase in the midge (nonbloodworm), black fly, and miscellaneous populations has occurred. The bloodworm population has remained stable from sites 5-10 making up a small percentage of the total community. When all sites are pooled, the bloodworms account for a larger percentage; this indicates that the main occurrence of bloodworms is from sites 2-4 which are largely impacted by the effluent. The bloodworms seem restricted to this zone; and once recovery occurs at or near Site 5, they no longer compete as well with the other organisms that gain dominance once the organic load is reduced. Thus, the overall community shift from Sites 5-10 appears not to be related to organic pollution but rather to another impact.

Table 6.13 presents these data grouped by site and date so that the overall shift in the community is viewed spatially as well as temporally. In all cases, the indicator community declines at Site 10, which is below the lower Indian Creek Wastewater Plant outfall. The reduction in numbers of this group can be attributed to wastewater effluent; thus, similar reductions that occur upstream in the absence of the wastewater impact are tied to other sources.

The Fall 1979 data have shown a recovery from the oil spill when evaluated by single number summaries. In terms of the organisms, however, it is seen that the black fly population has increased above the 1978 level and is responsible for a large part of the increase in total numbers seen before. The indicator community is present but did not recover as quickly as the black flies.

Summer 1980 data clearly show the decreasing impact of the effluent through Site 6, indicated by the decline in bloodworms, and the subsequent increase in indicators downstream with Site 10. During this time the black flies were still present in high numbers. Spring 1981 data further illustrate the effluent impact from Site 1 to Site 5. The indicator community was small during this time, with the majority of organisms in the midge and black fly group. However, this is at least partly attributable to seasonal effects. In Summer 1981 the black flies have declined, and the indicator group and midges fluctuate as being dominant. In Fall of 1981, again is seen the shift in the community as compared to Fall 1978. The indicator community has declined in importance with black flies and the tolerant miscellaneous group increasing in importance. Spring 1982 data reflect seasonal trends with the dominance of midges and black flies.

Even accounting for seasonal impacts, the partitioning of the data in this way demonstrates the decreasing impact of the effluent, and the subsequent community shift downstream from the baseline indicator community to a dominance of black flies, midges, and the tolerant miscellaneous group.

Table 6.13
Community Composition by Major Group
Percent of Total by Site and Date

	1	2	3	4	5	6	7	8	9	10
Fall 78										
MF,CF,RB					57		92.85	87	80	4
NBW					35		2.0	3	2.0	52
BW					0.4			0.2	1.0	2.8
BF					1.6		0.15			0.2
Misc.					6		5.0	9	17	41
Summer 79										
MF,CF,RB					1.0	7	23	11	32	2
NBW					44	50	47	22	32	63
BW					1.0				1.0	11
BF										
Misc.					54	43	30	67	35	24
Fall 79										
MF,CF,RB					7	33	30	38	68	4
NBW					26	22	9	15	13	59
BW					23					
BF					40	42	55	41	1	3
Misc.					4	3	6	6	18	34
Summer 80										
MF,CF,RB	75		1	2.0	4	23	59	61	64	7
NBW	1.0			4	23		12	15	2.0	41
BW		50	82		37	10				
BF			11	23		48	18	14	16	3
Misc.	24	50	6	71	36	19	11	10	18	49

Table 6.13 (cont.)

	1	2	3	4	5	6	7	8	9	10
Spring 81										
MF,CF,RB	3	1.0				11	7	11	12	0.5
NBW	42		7.9	36	72	66	42	62	19	53
BW	4	99	17	1.6	1.0	3	2	2	2	0.5
BF			75	60	4	10	13	3	43	
Misc.	51		0.1	2.4	23	10	36	22	24	46
Summer 81										
MF,CF,RB	91			7.4	20	92	36		95	20
NBW	4	6			77	1.8	56		2.4	74
BW		94		87			3.4		0.1	0.4
BF				0.1	2	0.6			1.5	0.1
Misc.	5			5.5	1	5.60	4.6		1.0	5.5
Fall 81										
MF,CF,RB	57		9.5		15	27	24	9.6	25	1.3
NBW			7		8	0.5	0.5	7	0.27	17
BW	1	98	0.5			0.5	0.5	0.40	0.23	3.3
BF	10		70		40	9	28	70	3.5	35
Misc.	32	2	13		37	63	47	13	71	43.4
Spring 82										
MF,CF,RB	13			1.0		14	1.0	8.4	18	3.0
NBW	14		45	41	53	50	48	56	49	37
BW		4	7	5	2	2	1	3.4	1	37
BF	7		45	37	29	29	48	16	28	1
Misc.	66	96	3	16	16	5	2	17	4	22

Key:

MF = Mayfly
CF = Caddisfly
RB = Riffle Beetle
NBW = Nonbloodworm
BW = Bloodworm
BF = Black fly
MISC = Miscellaneous

CONVERSION TABLE

1 MGD = 1.548 cfs

1 ft^3 = 7.481 gallons

1 gallon = 3.785 liters

1 acre = 4.356×10^4 ft^2

1 square mile = 640 acres

1 lb/acre = 1.12 kg/ha

1 (mg/l) · (ft^3) = 6.243×10^{-5} lbs

1 lb = .454 kg

1 ha = 2.471 acres

GLOSSARY

ANOVA - Analysis of variance; a statistical method used to examine the sources of variability in data.

Antecedent Dry Period - The number of dry days preceeding a storm event.

Background Load - The load transported by the stream not related to storm runoff loads.

Base Flow - Dry weather flow; same as low flow.

Basin - See watershed.

Basin Slope - The slope of the land on the sides of the main drainage channel.

Benthic, Benthos - Bottom dwelling organisms.

BOD - Biological (or Biochemical) five day oxygen demand; the amound of oxygen that will be removed from a sample in five days due to the degrading of biodegradable organics by bacteria.

Cd - Cadmium; a heavy metal with toxic effects.

cfs - Cubic feet per second; a unit of flowrate usually used in streamflow calculations.

Channel Slope - The slope of the main drainage channel.

Cl^- - Chloride; a component of salt, NaCl.

COD - Chemical Oxygen Demand; the total oxygen demand from all sources in a sample, including nonbiodegradable ones.

Coliforms - Bacteria that indicate the presence of pathogenic viruses and bacteria.

DO - Dissolved Oxygen.

Effluent - The product of a point source; a treatment plant produces treated sewage as effluent.

EPA - Environmental Protection Agency

Erosion - The removal and transport of soil particles, usually caused by rainfall and runoff.

Eutrophication - The overfertilization of a lake by nutrients such as phosphorus or nitrogen, causing an overgrowth of aquatic plants.

Event - A storm causing runoff; also called a storm event or runoff event.

Fe - Iron; a metal that causes taste problems in water.

Hazardous Nonpoint Source Zone - A specific area producing very high nonpoint source pollutant loadings, such as a gully, construction site, plowed field, large parking lot, or industrial area.

Hydrologic - Relating to the movement of water either as precipitation, runoff, stream flow, or groundwater.

Impervious Area - The amount of paved and roof area in a watershed that does not allow rainwater to soak into the soil.

JCUWD - Johnson County Unified Wastewater Districts

Load, Loading - The mass of pollutants produced by a storm event; usually expressed in pounds or pounds per event, also represents an annual load calculated from several storm events.

Low Flow - Dry weather flow; same as base flow.

Load-Runoff Curve - A simple flow-weighting model where a runoff volume is multiplied by a load-runoff curve slope to produce a pollutant load.

GLOSSARY (cont.)

Macroinvertebrates - Relatively large organisms with no backbone, such as insects.

MARC - Mid-America Regional Council.

MGD - Million gallons per day; a unit of liquid flowrate commonly used for urban water systems.

mg/l - milligrams/liter; a unit of concentration.

Mn - Manganese; a metal that causes taste problems in water.

Na - Sodium; a metal that forms sodium chloride or table salt.

NH_3 - Ammonia nitrogen; a semi-toxic form of nitrogen that oxidizes (takes up oxygen) to form nitrite (NO_2) then nitrate (NO_3).

NO_2 - Nitrite nitrogen; the intermediate form of nitrogen formed after the oxidation of ammonia and befor the oxidation to nitrate.

NO_3 - Nitrate nitrogen; the biologically available form of nitrogen.

Nonpoint Source - A pollutant source originating from a relatively large diffuse area, such as an entire watershed or an area of land.

Normalized Loads - Loads divided by watershed area: pounds per acre, or by time: pounds per year, or more commonly by both: pounds per acre per year.

NURP - Nationwide Urban Runoff Program

Oxygen Depression/Depletion - The removal of dissolved oxygen in water usually caused by the addition of pollutants with a high BOD or COD.

Pb - Lead; a heavy metal with toxi effects.

pH - The measure of acidity.

PO_4 - Orthophosphate; the form o phosphorus that is immediately available for uptake by aquatic plants.

Point Source - A pollutant source originating from a defined pipe or ditch such as a treatment plant or industry

Q_B - Base flow in cfs.

Q_P - Peak flow in cfs.

Regression - A mathematical techniqu used to develop equations expressing group of data.

Runoff Volume - The amount of runof produced by a storm event; expresse in cubic feet (ft^3).

SCS - Soil Conservation Service

Site - Same as station.

SJVI - Sample Jug Volume Indicator.

SPSS - Statistical Package for th Social Sciences; the computer packag used for the NURP data analysis.

Station - The site of a monitoring installation.

Storm Sewer - A system of concret clay, or metal undergound pipes replac ing the natural drainage system.

Swale - A grassy yard ditch; usually area is drained by swales or curb a gutters.

Taxa - A large classification of orga ism types, incorporating many spec per taxa.

GLOSSARY (cont.)

TKNS - Total Kjeldahl Nitrogen-Soluble; TKN in the soluble form.

TKNT - Total Kjeldahl Nitrogen-Total; an analysis method for nitrogen measuring organic and ammonia nitrogen. TKNT represents TKN in both the soluble and particulate phase.

TOTN - Total Nitrogen; the amount of nitrogen in all forms: organic, ammonia, nitrate, and nitrite. Nitrogen is a nutrient; ammonia is a semi-toxic form, nitrate and nitrite are biologically available for plant uptake, and organic nitrogen is bound up in plant tissue.

TPS - Total Phosphorus-Soluble; the amount of phosphorus in all forms in only the soluble phase.

TPT - Total Phosphorus-Total; the amount of phosphorus in all forms in both the soluble and particulate phase. Phosphorus is a nutrient and is found in the organic form and biologically available (PO_4) form.

TSS - Total Suspended Solids; the amount of sediment in the water.

Washoff - The removal of accumulated pollutants from impervious surfaces by the flushing action of runoff.

Watershed - The area drained by a common single point in stream; same as basin.

Zn - Zinc; a heavy metal with toxic effects.

µg/l - micrograms/liter; a unit of concentration; 1000 µg/l = 1 mg/l

ADDENDUM
NURP FINAL REPORT

Responses to comments from the Kansas Department of Health and Environment

1a. Baseline water quality conditions for the larger mixed watersheds are presented in the Dry Weather Pollutant Concentrations and Dry Weather Pollutant Loading sections for the land use stations. Only Station II had baseflow. No low flow sampling was performed due to the low discharge during dry weather at this site.

b. Pollutant export values were reported as a function of runoff in the modeling analysis to increase the accuracy of the assumptions. Site specific data can be used to determine runoff, which can then be applied to the generalized load-runoff curves. This approach is more accurate than a simple precipitation-pollutant load relationship because the use of specific site data can reduce some of the wide variation between similar land uses.

c. The duration of pollutant concentrations during individual storms was not measured by the NURP project; the EPA required flow composite sampling (where only one representative sample is collected per storm per site) to be performed to maximize the amount of pollutant loading data.

d. Benthic sampling was the only biological sampling approved by EPA in order to concentrate resources on obtaining pollutant loading data. The benthic sampling was only performed in the mixed land use Indian Creek Basin.

e. Benthic sampling was performed on a spring, summer and fall basis and direct, mechanistic interpretations could not be deduced from the data. The only hydrologic criteria used was to allow at least a week after a large storm to allow benthic recolonization.

f. Only minor uses of the streams were observed during the NURP study. Fisherman were observed only a few times after heavy rains washed fish populations out of upstream farmponds in Indian Creek. A pool in Rock Creek was sometimes used by fisherman during dry weather. Several canoeists and other contact related recreationists were also observed during high water during the course of the project. The Brookridge Golf Course uses Indian Creek water for irrigation. Finally, the Indian Creek floodplain is used as parkland, and picnicing, jogging, and bicycling facilities are often close to the creek.

It is difficult to determine if urban runoff impairs any of these uses; an increase in contact recreation might result from improved runoff quality. Since urban runoff appeared to deliver less sediment into the stream than upstream agricultural land in Indian Creek, it might enhance water use to some degree.

2. The difficulty in operating and analyzing samples from the monitoring network prohibited the collection of a complete set of samples from all stations. When a complete record was obtained, nearby stations during the same storm often produced greatly different precipitation records due to the track of thunderstorm cells. This lack of a consistent "control" prevented the direct comparison of data and required using the assumption that the data from each station was representative of an entire year of different sized storms. Median values were used to compare data sets and the ANOVA analysis was performed using pairwise rather than listwise deletion.

3. These corrections have been included in the technical report.

4. The Precipitation Based Method is used to estimate average annual loads from a set of sampled storms. Because of the extreme cost and difficulty in sampling every storm during an average runoff year a portion of a year's precipitation was actually monitored. The distribution of the monitored storm events was assumed to be close to the actual distribution of a year's worth of runoff. This assumption, which was used by several other urban runoff studies, was probably within the limits of accuracy for the entire monitoring programs as all four seasons were monitored and missed storms occurred on a relatively random basis.

State of Kansas . . . John Carlin, Governor

DEPARTMENT OF HEALTH AND ENVIRONMENT

Barbara Sabol, Secretary

Forbes Field
Topeka, Kansas 66620
913-862-9360

April 5, 1983

Mr. Cecil Taylor
Kansas Planning Coordinator
U.S. Environmental PRotection Agency
324 E. 11th
Kansas City, Mo. 64106

Dear Mr. Taylor:

We completed our review of the Mid-America Regional Council's report on the Nationwide Urban Runoff Program·study and offer the following comments and suggestions:

1. It is extremely difficult to derive study results from the report in its present form. The report must contain a summary of findings and conclusions including tables showing:
    a. Baseline water quality conditions for different land use configurations.
    b. Pollutant export per inch of rainfall for different land use configurations.
    c. Duration of elevated pollutant concentrations per inch of rainfall for different land use configurations.
    d. Biological communities for different land use configurations.
    e. Impact of runoff event on biological communities, i.e. did high flow flush or otherwise import community and if so how long did it take for recolonization.
    f. Water use inventory of impact area and impairment of those uses due to urban runoff.
2. Several statements refer to residential runoff containing heaviest pollution concentrations. The data summaries indicate that fewer samples of residential runoff were collected than those representing commerical or industrial areas. The data sets are therefore not necessarily comparible and means derived from the data sets may not be comparible. The data should be further refined so that it can be determined if this conclusion is valid.

3. The section which compares sampling results to water quality standards is in error in its interpretation of the Kansas standard for ammonia. The section refers to a standard of 0.15 mg/l total ammonia; the actual standard is 0.15 mg/l unionized ammonia, which is substantially different.

4. The Precipitation Based method does not take into account varying rainfall conditions such as three large events of three inches each as opposed to nine events of one inch each.

5. It would be interesting and beneficial to predict improvement through computer modeling assuming that an erosion control ordinance were in effect. It would provide us with information relative to the need for urban runoff treatment to eliminate water use impairment.

6. "F. X. Browne Associates, Inc." on each page is distractive and shall be omitted.

Obviously, a great deal of effort has gone into the report and we believe that with a little fine tuning it could be utilized more efficiently as a management and planning tool.

Thank you for the opportunity to comment.

Sincerely,
DIVISION OF ENVIRONMENT

W. L. Wagner

Walter L. Wagner
Environmental Engineer
Water Quality Management Section

cc: David Garcia
Charles A. Stiefermann
Ralph Hazel
John Metzler

RESPONSES TO COMMENTS FROM U.S. EPA HEADQUARTERS

1. While the development of BMPs was included as an objective in the Kansas City Nurp workplan, it was anticipated that time and resources would necessitate that this task be carried out as a second phase of NURP.

2. The MARC Model Grading and Sediment Control and Stormwater Runoff Management Ordinance are model ordinances. We do not expect any immediate change in the enforcement policies of local governments as a result of the findings of NURP.

3. See responses to EPA comment #3.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

May 31, 1983

Dave Garcia
Mid-America Regional Council
20 West Ninth
Suite 200
Kansas City, Missouri 64105

Dear Dave:

I have reviewed the draft version of the Kansas City NURP Final Report. The report was very well done. It was well organized and thoroughly covered the major items. I have only a few minor comments. Following are the comments:

1. The stated objectives include the development of BMPs. This did not seem to be carried through in the report.
2. Will the ordinance still be enforced in light of the findings of the NURP project?
3. A section on "Conclusions and Recommendations" should be included in the report. What can MARC say about the urban runoff problem in Indian Creek and Rock Creek. Is there a problem, what is the extent of the problem. Also, what is MARC going to do from here on out. Will any further work be done?

Those are all my comments. If you have any questions, give me a call at 202/382-7108.

Sincerely yours,

Patty Bubar

Patty Bubar
Environmental Engineer
Urban Nonpoint Source Section (WH-554)
Implementation Branch

EXECUTIVE AND TECHNICAL SUMMARIES

Responses to comments from U.S. EPA Region VII.

2. This recommendation is included in the summaries.

3. Urban runoff is probably not a significant water quality problem in Indian Creek or Rock Creek. Many of the pollutants generated and transported by runoff would be a problem for a conservative receiving water, such as a lake. The effects of urban runoff in these creeks however, are relatively shortlived, occur during wet weather periods where there is little recreational opportunity, and are quickly transported downstream.

   The two most significant runoff related problems are the high erosion related loads and the high coliform counts. The amount of sediment produced by urban runoff can reduce the capacity of important storm sewer systems, blanket stream bottoms with deposits, and create severe turbidity problems in a critical receiving waters. High coliform counts in runoff indicates that bacteria contamination makes contact recreation unhealthly.

   The most significant water quality violation relates to the high coliform count. Although both creeks would probably be lightly used (if at all) for contact recreation during high flow, the high coliform count suggests wet weather contact recreation should be avoided.

   Many of the wet weather Rock Creek stream samples (22 of 29) violated drinking water standards for lead. In comparison the U.S. Public Health Service reports that 27% of U.S. water supplies sampled by the USPHS exceeded this criteria. The median concentrations of lead found in these runoff samples were lower than concentrations affecting fish mortality.

   The apparent dissolved oxygen depression caused by urban runoff produced a D.O. value as low as 3.1 µg/l. However, only 9% of the samples at the downstream station, ISS, were below 5 µg/l.

   Probably few uses of Indian Creek and Rock Creek are being restricted by urban runoff.

   The removal of pollutants from drinking water is a complex process and depends on a variety of factors, such as pH during treatment, coagulant type and dose, use of prechlorination, intake water turbidity, and the concentration form and valence of the pollutant. The Manual of Treatment Technology for Meeting Interim Primary Drinking Water Regulations (U.S. EPA 600-8-77-005) was used to provide these general estimates of priority pollutants that could not be removed using available techniques:

   Barium using iron or alum coagulant
   Mercury using iron or alum coagulant
   Selenium using lime coagulant
   Organic pesticides

TECHNICAL REPORT

1. The changing of sampling intervals was designed to maximize the number of sample aliquots per sample, increasing the accuracy of the sample. The changes were made throughout the project to reflect increased knowledge of each station's hydrologic response, equipment modifications, and attempts to sample different sizes of storms.

   The flow compositing method produced sample aliquots related to flow rather than time. Specific time related points on the hydrograph were not the same for any two stations or any two storms at the same station. The number of sample aliquots varied with storm size and flowmeter-sampler programming and ranged from three to over 150 aliquots per sample. The goal of the sampling was to obtain the largest number of aliquots per sample for the widest range of storm sizes.

2. The May 15, 1982 sample at station RR was not excluded from the data analysis because onitoring problems were not observed by the field crews and conditions seemed to indicate high erosion potential. The sample crews observed nothing unusual about the collection except the sample was extremely turbid. Both flowmeter and sampler appeared to be operating normally and a large number of aliquots (92) were collected. The sample was analyzed twice in the lab to verify the result.

   On May 15, 1983 the soil was saturated from a rain about twelve hours earlier, and the rain that produced the event was about an inch and a half with a high intensity.

   Because of the lack of any monitoring failure, the corresponding physical factors, and the extremely high TSS values recorded at this site from other storms the sample was left in the data analysis.

3. Dr. Tom Grizzard of Virginia Polytechnic Institute and Director of the Occoquan Watershed Monitoring Laboratory (Washington D.C. NURP) said he felt the holding times were not firmly backed-up with conclusive data. Our opinion is that several additional months probably has little effect on the acidified samples.

4. The City of Independence Water Pollution Control Department reported no permitted dischargers above their discharge on Rock Creek.

5. The Rock Creek dry weather mean zinc concentration was about twice as high as median wet weather concentrations. The maximum zinc concentration in Rock Creek runoff was higher than the maximum dry weather concentration (3,200 µg/l to 2,360 µg/l). The maximum Indian Creek values were 2,770 µg/l for runoff compared to 2760 µg/l for dry weather. This comparison shows some source is elevating low flow Rock Creek zinc concentrations to levels near or above normal urban runoff concentrations, although lower than the maximum urban runoff concentrations.

6. The two violations occurred during low flow, hot water conditions which reduce dilution of upstream BOD and COD sources and decreases oxygen solubility. One occurred almost a year after the second, suggesting that a temporary or unusual phenomenon was not responsible. No further mechanistic interpretation could be made with the available data.

7. No stream samples were found to exceed the drinking water criteria (1 µg/l) so no impact on beneficial uses occurred.

8. See comment 2.

9. The large Sterling project began March 16, 1981 and is still underway. The City reported that the actual bridge work between 19th and 20th streets across the Rock Creek did not start until after the end of sampling. The maximum area exposed during construction were:

1981 (20th St. to 34th St.)	19 acres
1982 (Truman to 19th St.)	1.4 acres

No discernable difference was observed between the two years, although the data variability was significant. Both means were with each other year's standard deviation:

	Mean TSS Load (tons)	Standard Deviation
1981	109	220
1982	321	403

Some events with similar total runoff showed similar loads, other comparisons showed great variability.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VII
324 EAST ELEVENTH STREET
KANSAS CITY, MISSOURI - 64106

MAY . 1983

Mr. Peter S. Levi
Executive Director
Mid-America Regional Council
20 West Ninth, Suite 200
Kansas City, Missouri 64105

Dear Mr. Levi:

Thank you for letting the Region review your two draft documents, "Executive and Technical Summaries" and "Technical Report" for the Nationwide Urban Runoff Program.

Your staff has already received a copy of the Kansas Department of Health and Environment's comments and has been making appropriate changes to the reports. The Kansas comments are incorporated in this letter by reference. The Missouri department of Natural Resources had no comment on the NURP reports.

The following are the Regional comments on the two documents.

GENERAL

1. Both documents should include the following disclaimer:

> Although the information in this document has resulted from activities funded wholly or in part by the United States Environmental Protection Agency under assistance agreement number P007062 01 to the Mid-America Regional Council, the document has been subjected to the Agency's peer and administrative review process and was not approved by the EPA for publication; it, therefore, does not necessarily reflect the views or policies of the Agency.

2. Pete Mangarella and Phil Shelly are not employed by EPA. They are contractors and should receive acknowledgement as such in the "Project Participants" listings.

3. Delete "F.X. Browne Associates, Inc." from the top of report pages.

EXECUTIVE AND TECHNICAL SUMMARIES

1. This document is long enough that a Table of Contents would be helpful.

2. MARC is recommending use of channel stabilization techniques when developing near steep channels. Has consideration been given to the safety considerations of this recommendation? Johnson County has done a lot of public relations work to keep children out of concrete lined ditches during storms. This may be a point worth mentioning as part of the MARC recommendation.

3. In the Executive Summary under Summary of Results add a paragraph which answers the following questions. In MARC's opinion, is Urban Runoff a problem in Indian Creek or Rock Creek? In MARC's opinion, are the water quality criteria violations significant? In MARC's opinion, are water uses being impacted? Did MARC find any priority pollutants which would not be removed by routine treatment in a drinking water supply treatment plant?

TECHNICAL REPORT

1. Page 1-15, Section 1.3.2, Runoff Quality, paragraph 2: How did the frequent changing of sampling intervals affect data? Were the changes such that all storm monitoring reflected sampling on the same points of the hydrograph, in particular, the RR station during the storm of May 15, 1982?

2. In General, why was the data from the storm of May 15, 1982 at station RR left in the report? This data seems to slant the report toward very high erosion rates, twice as high as any other event at the site. This is then reflected throughout the report and found as supporting MARC recommendations for erosion control.

3. Page 1-36, Section 1.3.7.1, Holding Times and Sample Preservatives, paragraph 5: This paragraph should be expanded by including the consultant's expert opinion on the effects of the long holding period for these heavy metal samples; i.e., analysis may have found lower levels of heavy metals than were actually present.

4. Page 2-2, Section 2.1.1.1, Concentration Summary, paragraph 2: Did MARC contact the State of Missouri DNR to verify whether or not there was an industrial discharge upstream of RS1? If this discharge exists, did it bias the Rock Creek Stream data? Note the comparison of zinc loads in the next to last paragraph on page 2-4. Is this a valid comparison if Rock Creek does have an industrial discharge?

5. Page 2-4, Section 2.1.2.1, Concentration Summary, next to last paragraph: This is an example of zinc in Rock Creek being five to ten times that of Indian Creek. If there is an industrial discharge in Rock Creek generating zinc, what value does this comparison have with respect to Urban Runoff?

6. Page 2-6, Section 2.1.2.1, Concentration Summary: What was the cause of the two Kansas Water Quality Standard violations?

7. Page 2-68, Section 2.5.2, Impact on Beneficial Uses: Copper has been omitted from the discussion.

8. Page 3-15, Section 3.2.1, Introduction, second paragraph: This raises questions as to why use the May 15, 1982 storm.

9. Page 3-42, Section 3.3.2, Land Use Loading Function Evaluation - "Hazardous Nonpoint Source Zones": Were the Independence street projects for Sterling and Chrysler in progress during the study period? These may have impacted the sediment loads bringing normal loads and calculated loads more in line with each other.

Mr. David Garcia of your staff has requested that changes be printed as an addendum to the final report. This is an acceptable method. It is requested that the addendum be formatted such that it can be posted in the document.

If you have additional questions, please contact me. The member of my staff who is most familiar with this subject, Mr. Cecil Taylor, (816) 374-2281, can also provide additional information.

Sincerely yours,

Allan S. Abramson, Ph.D.
Director, Water Management Division

cc: Don Snethen, Kansas Dept. of Health and Environment

John Howland, Missouri Dept. of Natural Resources

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